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A SURVEY OF CENOZOIC MAMMAL BARAMINS

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ABSTRACT

To expand the sample of statistical baraminology studies, we identified 80 datasets sampled from 29 mammalian orders, from which we performed 82 separate analyses. We analyzed each dataset with standard statistical baraminology techniques: baraminic distance correlation (BDC) and multidimensional scaling (MDS). We evaluated the BDC and MDS results from each character set for potential continuity and discontinuity. We found evidence of holobaramins in 57 of the 82 analyses (69.5%). Of the remaining character sets, three showed evidence of monobaramins and 22 (26.8%) were inconclusive. These results are consistent with previous efforts to test the discontinuity hypothesis, which found that a majority of character sets showed evidence of holobaramins. Tentative holobaramins represent 57 taxonomic groups, many of which have not been previously analyzed by statistical baraminology. Together with previously identified holobaramins, this study increases the number of putative mammal holobaramins to 64.

KEY WORDS

baramin, created kind, baraminology, mammal, Cenozoic, post-Flood, baraminic distance correlation (BDC), multidimensional scaling (MDS)

INTRODUCTION

The concept of the created kind—a group of modern species connected by common ancestry to a population created *ex nihilo* by God—has a long history in creationist thought. Initially suggested before the publication of Darwin's *Origin* by scholars such as Linnaeus and Herbert, creationists throughout the twentieth century have endorsed the created kind as a contrast to species fixity (Wood 2008a). More recently, creationists have produced several large-scale estimates of mammalian created kinds (e.g., Wise 2009; Wood 2011; Lightner 2012).

Although there has been much written about created kinds, statistical baraminology is a comparatively underserved field of research. Few created kinds have been established unequivocally using statistical studies, and even for those taxa which have been investigated, the datasets suitable for baraminological calculations and the reliability of the methods used have rarely been confirmed (Wood 2016a). Some outstanding questions include:

- Are holobaramins marked by discontinuity with all other organisms, defined as "significant, holistic difference" (Wood et al. 2003)?
- Is discontinuity detectable by current statistical baraminology methods?
- What sorts of character or taxon samples are most suitable for statistical baraminology methods?

Previously, Wood (2009) evaluated a collection of 73 baraminology analyses to answer some of these questions. Assuming that discontinuity would distinguish baramins approximately at the taxonomic level of family, he found 62% of analyses revealed discontinuity as predicted, although the fraction was not statistically significant.

This project focused on the mammals of the Cenozoic, more than doubling the number of previous statistical baraminology studies. Mammals are particularly interesting to creationists because of the numerous stratomorphic series like the famous horse series and because of their affinity to humans. The primary purpose of this work is to provide a database of statistical baraminology studies for future meta-analyses to shed light on such pressing topics as post-Flood diversification, microevolution and speciation, biological imperfection, endemism, and biogeography. We here focus on the question of whether discontinuity distinguishes mammalian families from other similar families and secondarily on the question of what combination of characters and taxa yield successful baraminology studies. These new analyses represent a large-scale first approximation of baramins from at least 79 mammal families.

MATERIALS AND METHODS

We collected character sets from the published literature identified using Google Scholar searches. We selected matrices that primarily focused on a single family or collection of families. We excluded redundant datasets on the same taxa and from the same author(s), and we used the most recent version available. In deference to the baraminological emphasis on holistic similarity and difference, we preferred datasets that had more taxa, characters, or both. In three cases, the kangaroos (Macropodidae), the new world monkey family Cebidae, and the South American notoungulates Interatheriidae, two separate datasets were included for each, since in each case the character and taxon selections were sufficiently different to consider them separately. We also excluded datasets of cetaceans and hominins, in anticipation of forthcoming and more detailed analyses than this simple overview. Six character sets with members from multiple families (Ornithorhynchidae, Felidae, Plesiadapidae, Picrodontidae, Lemuridae, and Omomyidae) were subdivided to include only taxa from an ingroup family and the nearest outgroup clade, and these taxonomic subsets were examined individually rather than *en masse*. For consistency, all selected datasets were organized and classified by family and order as listed in McKenna and Bell (1997), even when such classification may be out of date.

Prior to any analyses, all hypothetical ancestral taxa were removed from the datasets. Baraminic distance correlation (BDC) and multidimensional scaling (MDS) were calculated using BDISTMDS (http://coresci.org/bdist.html). For each baraminology analysis, we recorded the same diagnostic statistics as in Wood's (2008b) previous survey of statistical baraminology studies. Analyses were classified as holobaramin, monobaramin, or inconclusive based on evaluation of the statistical baraminology results. Ideally, a holobaramin can be revealed by BDC showing significant, positive BDC between all members of the holobaramin and significant, negative BDC between the holobaramin members and all outgroup taxa. In practice, this pattern rarely obtains. Alternative patterns include significant, positive BDC between ingroup and outgroup and significant, negative BDC between taxa that also share significant, positive BDC with the same third taxon. MDS aids in the interpretation of the BDC results by confirming clusters of taxa reflected in the BDC results or by revealing complex geometric shapes of taxa (e.g., lines, arcs, or tetrahedra) that cause uninterpretable BDC patterns. Analyses that did not reveal clear clusters of taxa were classified as inconclusive.

RESULTS

We collected 80 character sets from the published literature, from which we performed 82 separate baraminology analyses. The types of characters were most frequently craniodental (43.9%), followed by craniodental with postcranial (28.0%). Only 11% included more types of characters (such as craniodental, postcranial, and soft tissue), and 9.8% consisted only of dental characters. Given the emphasis on holistic analysis in baraminology (Wood et al. 2003), analyses that use more types of characters should be preferred to analyses that use fewer. Especially tentative are any conclusions based solely on dental characters.

We discovered evidence of discontinuity around a holobaramin in 57 (69.5%) of the 82 analyses. Three additional analyses (3.7%) revealed evidence of continuity without discontinuity (monobaramins), and the remaining 22 analyses (26.8%) were classified as inconclusive. A complete account of all results with references is included in the appendix.

Of the 57 analyses that revealed a putative holobaramin, 25 were based on craniodental characters (43.9%), 15 on craniodental and postcranial characters (26.3%), and 6 on dental characters only (10.5%) (see Table 1). These fractions are not substantially different from the overall frequency of character types in the full set of 82 datasets. Of the 22 analyses that were inconclusive, 11 were based on craniodental characters (50.0%), 7 on craniodental and postcranial characters (31.8%), and only two on dental characters only (9.1%). Again, these fractions are not substantially different from the full set of datasets.

The number of taxa and characters used in the analyses that revealed holobaramins were not significantly different from those that resulted in inconclusive results (Table 2). For the MDS analyses, the stress at three dimensions and the dimensions of minimum stress (k_{min}) also did not differ significantly between analyses that identified holobaramins when compared to those that did not. In the BDC analyses, the median bootstrap value and the fraction of correlations with bootstrap values >90% (F_{90}) were also not significantly different in BDC analyses that revealed holobaramins than in those that did not.

Based on the successful analyses, we identified 59 putative holobaramins, 49 of which corresponded to families, seven to subfamilies (or portions of families), two to superfamilies (or multiple families), and one (Sirenia) to an infraorder (Table 3). Our results reveal the first five Australian marsupial holobaramins identified by statistical baraminology: the extinct Palorchestidae, the rat kangaroos Hypsiprymnodontidae, the kangaroos Macropodidae, ringtail possums Pseudocheirinae, and the koalas Phascolarctidae. Other notable holobaramins first identified here include the Ornithorhynchidae (platypus), the Mephitidae (skunks), and the Sirenia (manatees).

Ten of these groups had already been studied in baraminology analyses (Table 3). Previously identified holobaramins confirmed by this study include Didelphidae (possums), Felidae (cats), Erinaceinae (hedgehogs), and Hippopotamidae (hippos). The Talpidae (moles) were previously inconclusive in Wood's (2009) study, but here they are identified as a holobaramin. The Ursidae (bears), Camelidae (camels), and Brontotheriidae were both previously identified as monobaramins (Wood 2016a), but here are recognized as holobaramins. Our present results also recognize two holobaramins within the Cingulata: Dasypodidae and Glyptodontinae. Previously, Wood (2008b) tentatively proposed that the entire Cingulata might have been a holobaramin, but these results suggest otherwise.

DISCUSSION

Our results substantially expand the available database of baraminology studies. Wood (2016a) previously identified 70 holobaramins identified in studies of 153 taxonomic groups. Our results expand the total number of taxonomic groups studied to 215 with 125 putative holobaramins identified. Within the non-hominin, non-cetacean mammals, we expand the putative holobaramins from 10 to 64. This remains far fewer than the total number of proposed mammal baramins. Assuming that the taxonomic family is roughly equivalent to the holobaramin, McKenna and Bell (1997) list 347 mammal families, of which 64 putative holobaramins is only 18.4%.

Our results agree closely with the mammal ark kind estimations of Lightner (2012). Lightner lists only extant mammals, of which 30 of our holobaramins overlap taxonomically with 30 of her ark kinds. In 28 cases, our holobaramin matches roughly equivalently with her ark kinds, but in three cases, they differ. Our analysis of lemurs identified Indriidae and Palaeopropithecidae as a holobaramin, but Lightner recognized only Indriidae. This could be merely a result of Lightner's exclusion of extinct taxa. In the other two cases, we found holobaramins that appeared to be taxonomically more restricted than Lightner's ark kinds. First, our study of the pigs, Suidae, identified the family as the holobaramin with putative discontinuity observed between the suids and the peccaries (Tayassuidae). In contrast, Lightner included both pigs and peccaries in a single ark kind. Lightner also included

Table 1. Character types in the datasets used in this study. "Holobaramin datasets" refer to datasets in which a putative holobaramin was identified, and "Inconclusive datasets" are datasets which produced inconclusive BDC and MDS results.

Character type	Frequency in all datasets	Percentage in all datasets	Frequency in holobaramin datasets	Percentage in holobaramin datasets	Frequency in inconclusive datasets	Percentage in inconclusive datasets
Craniodental	36	43.9%	25	43.9%	11	50.0%
Craniodental + postcranial	23	28.0%	15	26.3%	7	31.8%
Dental	8	9.8%	6	10.5%	2	9.1%
>3 types	9	11.0%	6	10.5%	1	4.5%
Cranial + postcranial	4	4.9%	4	7.0%	0	0.0%
Dental + postcranial	1	1.2%	0	0.0%	1	4.5%
Cranial	1	1.2%	1	1.8%	0	0.0%

Table 2. Comparison of results between datasets for which a holobaramin was identified and datasets which produced inconclusive results. Welch's unequal variance *t*-test was used to compare the holobaramin and inconclusive datasets.

	Holobaramin dataset mean	Inconclusive dataset mean	Welch's *t*	P-value
Taxa in analysis	21.9	26.6	-1.08	0.2915
Characters in analysis	71.4	66.1	0.38	0.7029
3D stress	0.16	0.17	-0.45	0.6528
k_{min}	6.2	6.0	0.19	0.8473
Median bootstrap	86.1	82.0	1.80	0.0800
F_{90}	0.44	0.34	1.98	0.0537

three genera (*Cyclopes*, *Myrmecophaga*, and *Tamandua*) from two families in the anteater kind Vermilingua, but our results support only *Myrmecophaga* and *Tamandua* in holobaramin Myrmecophaginae. These results will need further evaluation in future studies to clarify these differences.

Wise's (2009) estimation of mammalian ark kinds differs substantially from all others in the creationist literature. His estimates are based on the Post-Flood Continuity Criterion (PFCC), which in turn is based on the proposal that an ark kind should leave a continuous fossil record from the Flood to the present. His minimal estimate places a large number of species into as few as 97 ark kinds, and his maximal estimate places fewer species into as many as 234 ark kinds. Not surprisingly, our putative holobaramins do not match his estimated ark kinds (Table 3). Instead, we find tentative evidence of discontinuity within 33 of his minimal ark kinds and 18 of his maximal ark kinds. Sixteen of our putative holobaramins match closely sixteen of Wise's maximal ark kinds. Resolving the discrepancy between Wise's results and ours will require assessments of the completeness of the post-Flood fossil record as well as further evaluations of our baraminology results.

Our results should also help creationists evaluate baraminology methods, which have recently come under scrutiny (Wood 2016b; O'Micks 2016; Wood 2017; O'Micks 2017). Previously, Wood's (2009) survey of 73 statistical baraminology studies examined taxon samples that should have revealed discontinuity as well as those that should not (such as within a single genus). Wood found that 61.6% of the studies were "successful" in either revealing or not revealing predicted discontinuity. Our survey differs in that we focused exclusively on datasets that should have revealed discontinuity around a taxonomic family, but we found 69.5% of studies revealed evidence of the expected discontinuity. This is an improvement from the previous survey, and the question remains: Why do some datasets reveal evidence of discontinuity while others do not?

We attempted to determine what sort of feature of the datasets might correlate or predict successful discontinuity detection by examining the number of taxa and characters, the stress and k_{min} of the MDS, and the median bootstrap value and F_{90} of the BDC results, but we found no significant correlations, as in previous studies. Future studies will definitely want to examine these results more closely to determine the type of dataset best suited to these studies.

Future studies should more closely evaluate individual taxonomic groups named herein, especially those where discrepancies between different studies are noted. The current best practice in statistical baraminology is to use multiple holistic character sets compiled from different sources to evaluate the baraminology of a single group, as in hominin baraminology (e.g., see Wood 2016c; 2017). Some of our studies add to baraminology studies of previous groups, while most provide only a first approximation of a group's baraminology. Nevertheless, the present results provide an important advance in baraminology work and in the study of mammalian created kinds.

Table 3. List of putative holobaramins identified in this study and comparable Ark kinds recognized by Lightner (2012) and Wise (2009). Also listed are previous baraminology studies recorded in Wood (2016a). HB = holobaramin; MB = monobaramin.

Order	Holobaramin	Rank	Previous Baraminology	Lightner's Ark Kinds	Wise's Minimal Ark Kinds	Wise's Maximal Ark Kinds
Platypoda	Ornithorhynchidae	Family		Ornithorhynchidae	Prototheria	Ornithorhynchidae
Diprotodontia	Palorchestidae	Family			Australidelphia	Australidelphia
Diprotodontia	Thylacoleonidae	Family			Australidelphia	Australidelphia
Diprotodontia	Hypsiprymnodontidae	Family		Hypsiprymnodontidae	Australidelphia	Australidelphia
Diprotodontia	Macropodidae	Family		Macropodidae	Australidelphia	Australidelphia
Diprotodontia	Pseudocheirinae	Subfamily		Pseudocheiridae	Australidelphia	Australidelphia
Diprotodontia	Phascolarctidae	Family		Phascolarctidae	Australidelphia	Australidelphia
Didelphimorphia	Didelphidae	Family	HB Didelphidae	Didelphidae	Didelphimorphia	Didelphidae
Sparassodonta	Hathliacynidae	Family			Sparassodonta	Sparassodonta
Cingulata	Dasypodidae	Family	HB Cingulata	Dasypodidae	Xenarthra	Dasypodidae
Cingulata	Glyptodontinae	Subfamily	HB Cingulata		Xenarthra	
Pilosa	Myrmecophaginae	Subfamily		Vermilingua	Xenarthra	Xenarthra
Leptictida	Pseudorhynchocyonidae	Family			Lepticida	Leptictidae
Rodentia	Castoridae	Family		Castoridae	Castorimorpha	Castorimorpha
Rodentia	Anomaluridae	Family		Anomaluridae	See Wise (2009) p. 151 for comments on Anomaluromorpha	
Rodentia	Caviidae	Family		Caviidae	See Wise (2009) p. 151 for comments on Hystricognatha	
Pholidota	Manidae	Family		Manidae	Pholidota	Manidae
Carnivora	Felidae	Family	HB Felidae	Felidae	Feliformia	Feliformia
Carnivora	Felidae	Family	HB Felidae	Felidae	Feliformia	Feliformia
Carnivora	Ursidae	Family	MB Ursidae	Ursidae	Caniformia	Caniformia
Carnivora	Otariidae	Family			Caniformia	Caniformia
Carnivora	Odobenidae	Family			Caniformia	Caniformia
Carnivora	Mustelidae	Family		Mustelidae	Caniformia	Caniformia
Carnivora	Mephitidae	Family		Mephitidae	Caniformia	Caniformia
Chrysochloridea	Chrysochloridae	Family		Chrysochloridae	See Wise (2009) p. 154 for comments on Chrysochloroidea	
Erinaceomorpha	Erinaceinae	Subfamily	HB Erinaceinae	Erinaceinae	Erinaceomorpha	Erinaceidae
Erinaceomorpha	Galericinae	Subfamily		Galericinae	Erinaceomorpha	Erinaceidae
Erinaceomorpha	Talpidae	Family	? Talpidae	Talpidae	Erinaceomorpha	Erinaceomorpha
Soricomorpha	Nyctitheriidae	Family			Soricomorpha	Nyctitheriidae
Soricomorpha	Soricidae	Family		Soricidae	Soricomorpha	Soriocoidea
Chiroptera	Rhinolophidae	Family		Rhinolophidae	Chiroptera	Yinochiroptera
Primates	Picrodontidae	Family			Picrodontidae	Picrodontidae
Primates	Plesiadapidae	Family			Plesiadapidae	Plesiadapidae
Primates	Lemuridae	Family		Lemuridae	Strepsirrhini	Lemuroidea
Primates	Indriidae + Palaeopropithecidae	Superfamily		Indriidae	Strepsirrhini	Lemuroidea
Primates	Lepilemuridae	Family		Lepilemuridae	Strepsirrhini	Lemuroidea
Primates	Cheirogaleidae	Family		Cheirogaleidae	Strepsirrhini	Lemuroidea
Primates	Carpolestidae	Family			Carpolestoidea	Carpolestidae
Primates	Omomyidae	Family			Tarsioidea	Omomyidae
Primates	Callitrichidae	Family			Anthropoidea	Anthropoidea
Condylarthra	Didolodontidae	Family			Didolodontidae	Didolodontidae
Artiodactyla	Suidae	Family		Suoidea	See Wise (2009) p. 157 for comments on Suoidea	
Artiodactyla	Hippopotamidae	Family	HB Hippopotamidae		See Wise (2009) p. 157 for comments on Suoidea	
Artiodactyla	Camelidae	Family	MB Camelidae	Camelidae	Cameloidea	Camelidae
Notoungulata	Leontiniidae	Family			Toxodontia	Toxodontia
Notoungulata	Toxodontidae	Family			Toxodontia	Toxodontia
Notoungulata	Interatheriidae	Family			Typotheria	Interatheriidae
Notoungulata	Hegetotheriidae	Family			Hegetotheria	Hegetotheria
Astrapotheria	Astrapotheriidae	Family			Astrapotheria	Astrapotheriidae
Xenoungulata	Carodniidae	Family			Xenungulata	Carodniidae
Perissodactyla	Palaeotheriinae s. l.	Subfamily			Hippomorpha	Palaeotheriidae
Perissodactyla	Brontotheriidae	Family	MB Brontotheriidae		Brontotherioidea	Brontotheriidae
Perissodactyla	Chalicotherioidea	Superfamily			Chalicotherioidea	Chalicotherioidea
Perissodactyla	Lophiodontinae	Subfamily			Tapiroidea	Lophiodontidae
Uranotheria	Sirenia	Infraorder			Sirenia	Sirenia
Uranotheria	Desmostylidae	Family			Behemota	Behemota
Hyracoidea	Procaviidae	Family		Procaviidae	Hyracoidea	Hyracoidea
Proboscidea	Gomphotheriidae	Family			Behemota	Behemota
Proboscidea	Elephantidae	Family		Elephantidae	Behemota	Behemota

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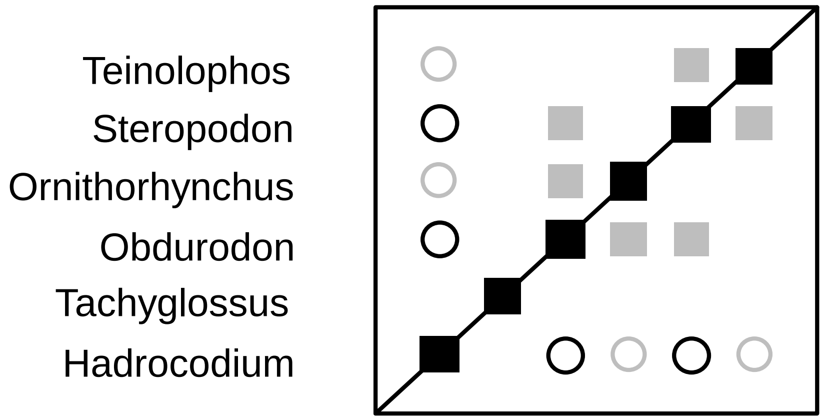
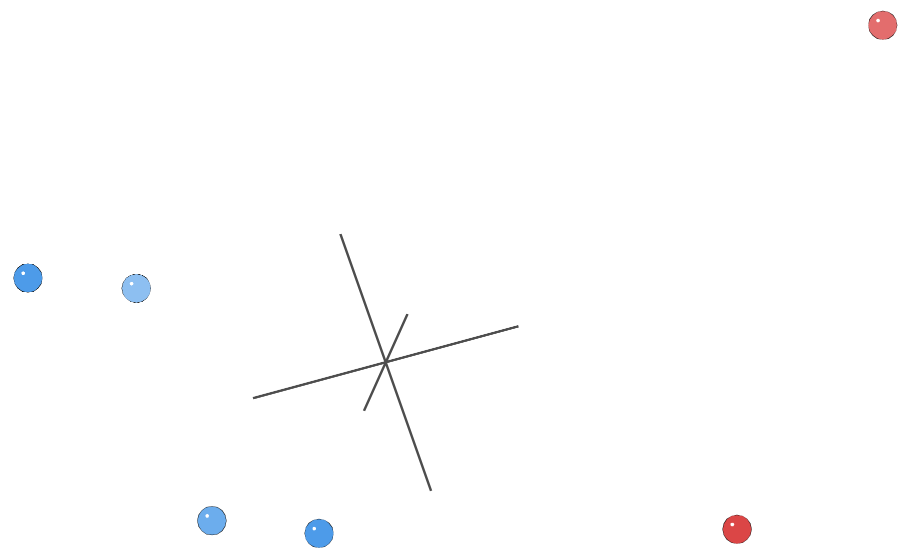
Appendix. BDC and MDS analyses of Cenozoic Mammalia

This appendix contains the results of all 82 BDC and MDS analyses. All baraminology analyses were conducted in BDISTMDS (coresci.org/bdistmds.html). For all Multidimensional Scaling (MDS) illustrations, outgroup taxa are shown in red and ingroup taxa in blue, unless otherwise indicated. Statistics for Baraminic Distance Correlation (BDC) and MDS are summarized in a table, as in Wood's (2008) "Animal and Plant Baramins." As in Wood (2008), F_{90} is the fraction of taxon pairs having bootstrap values >90%, and k_{min} is the MDS dimensionality at which the minimum stress is observed. A conclusion is also included in the table (HB = holobaramin, HB? = provisional holobaramin, MB = monobaramin, and Inc = inconclusive). The conclusion is briefly explained for each data set. The taxa are classified and ordered as in McKenna and Bell (1997). An index of the mammal taxa is provided below, page numbers are indicated at the bottom right of each page.

Rowe, T., T.H. Rich, P. Vickers-Rich, M. Springer, and M.O. Woodburne. 2008. The oldest platypus and its bearing on divergence timing of the platypus and echidna clades. *Proceedings of the National Academy of Sciences USA* 105:1238-1242.
Characters: Craniodental and postcranial



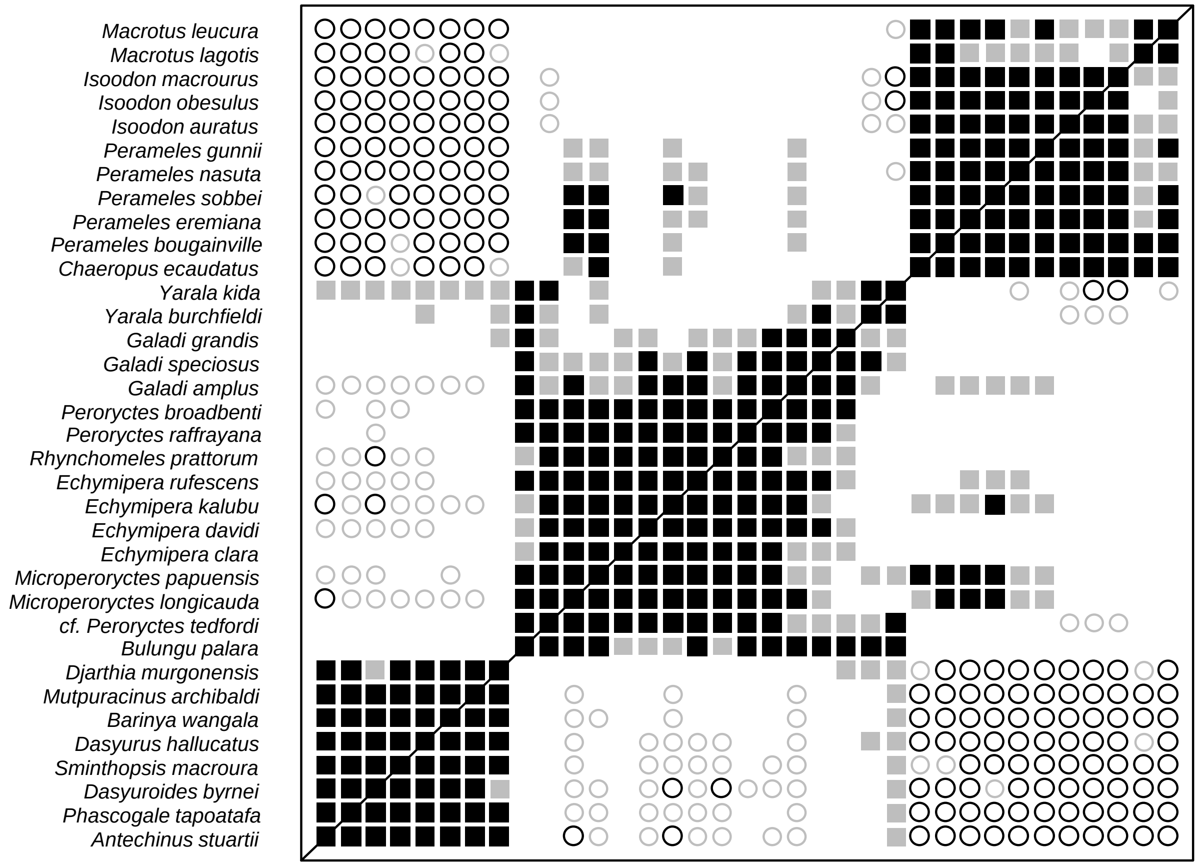


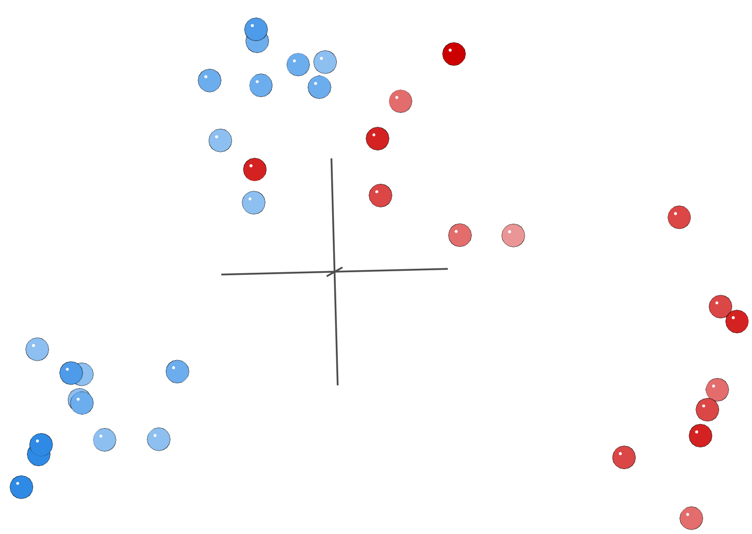
Order Platypoda
Family Ornithorhynchidae

Published taxa	6
Published characters	390
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	6
Characters used for calculations	50
Median bootstrap value	91
F_{90}	0.53
Stress of 3D MDS	0.15
k_{min}	2
Conclusion	HB?

Notes: Character set has been reduced to just Monotremata from the published dataset. BDC results have poor bootstrap values, and MDS reveals a disperse cloud of taxa. Nevertheless, ornithorhynchids share significant, positive BDC, and are noticeably separated from outgroup taxa in MDS. We may provisionally accept holobaramin Ornithorhynchidae.

Travouillon, K.J., S.J. Hand, M. Archer, and K.H. Black. 2014. Earliest modern bandicoot and bilby (Marsupialia, Peramelidae, and Thylacomyidae) from the Miocene of the Riversleigh World Heritage Area, Northwestern Queensland, Australia. *Journal of Vertebrate Paleontology* 34:375-382.
Characters: Craniodental





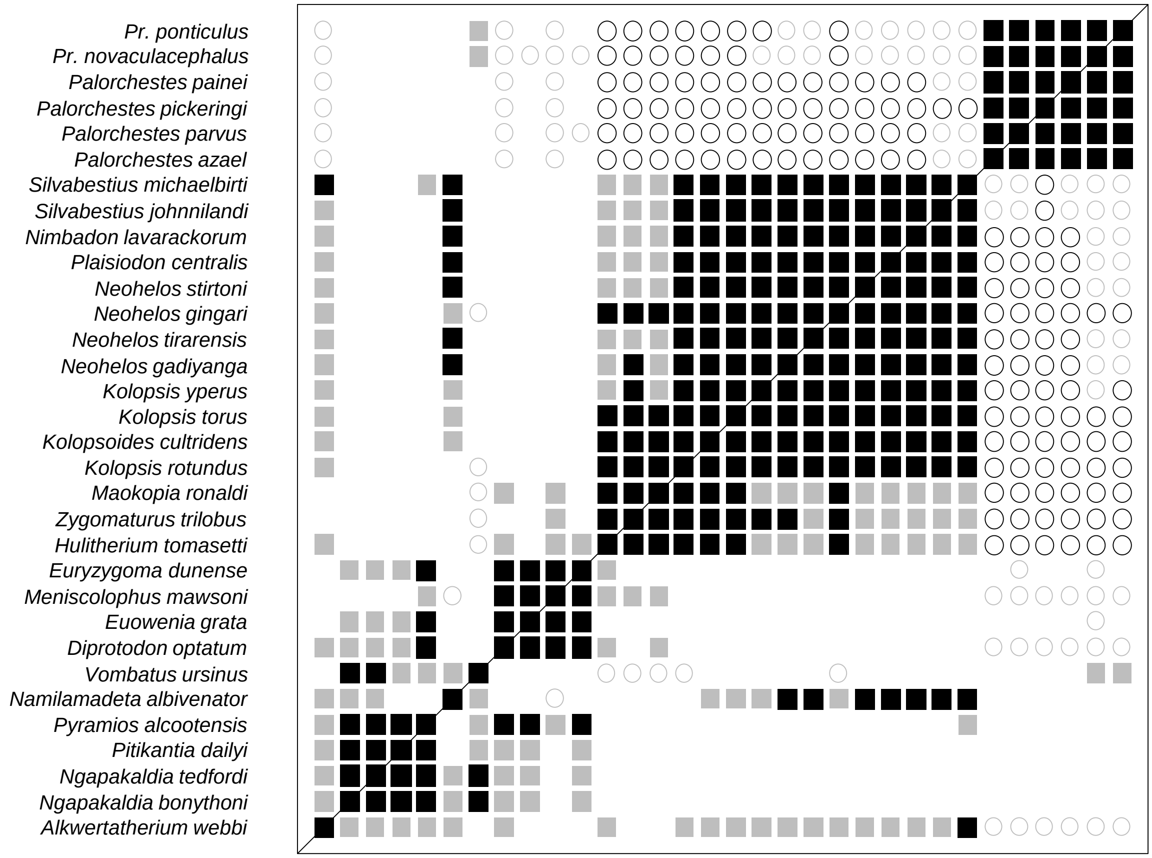
Order Peramelia
Family Peramelidae

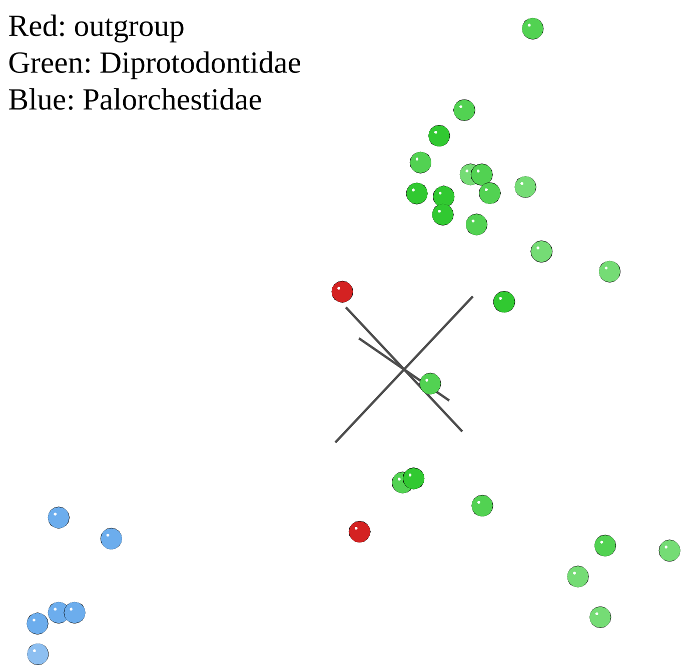
Published taxa	42
Published characters	156
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	35
Characters used for calculations	140
Median bootstrap value	91
F_{90}	0.52
Stress of 3D MDS	0.26
k_{min}	12
Conclusion	Inc

Notes: Three groups appear in both BDC and MDS: one with only peramelids, one with only outgroup taxa, and one with both. BDC and MDS do not support a clear holobaramin, even provisionally.

Black, K. 2008. Diversity, Phylogeny and biostratigraphy of Diprotodontoids (Marsupialia: Diprotodontidae, Palorchestidae) from the Riversleigh World Heritage Area. Ph.D. Dissertation. Sydney, Australia: University of New South Wales.

Characters: Craniodental



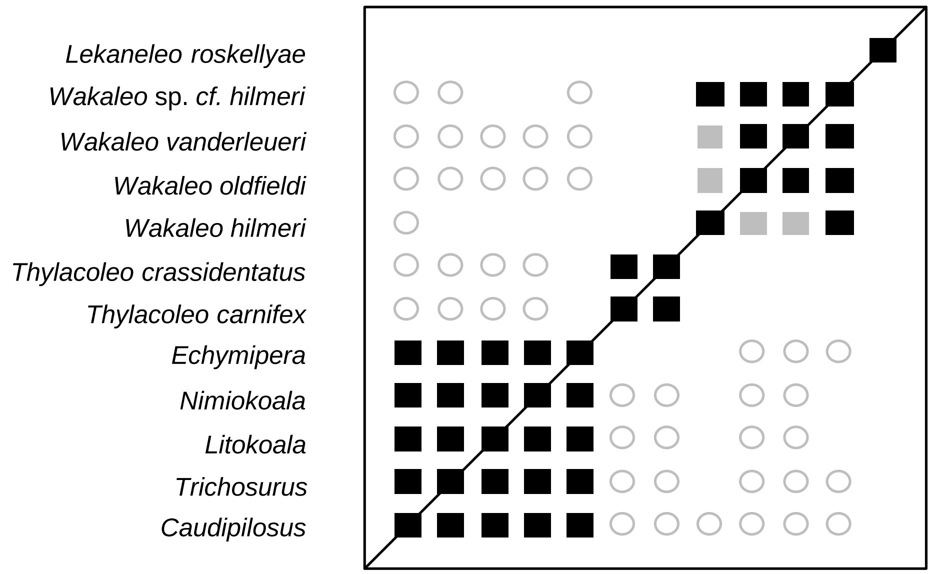


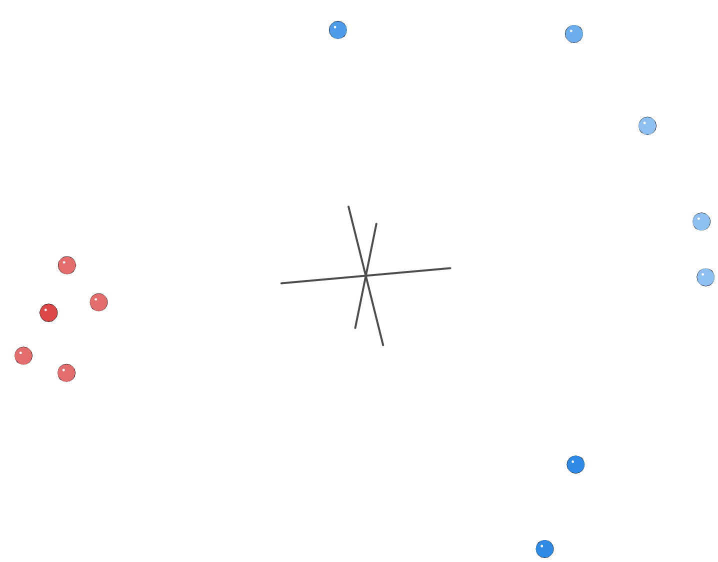
Order Diprotodontia
Family Palorchestidae

Published taxa	35
Published characters	77
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	32
Characters used for calculations	57
Median bootstrap value	79
F_{90}	0.39
Stress of 3D MDS	0.1
$k_{\min}$	4
Conclusion	HB

Notes: This character set is taken from chapter ten of Black's dissertation. BDC appears to support clear separation of palorchestids from outgroup taxa, except for *Vombatus ursinus*, which is correlated positively with two palorchestids (but with low bootstrap values). The MDS definitely supports an inference of discontinuity between Palorchestidae and the outgroup taxa. Palorchestidae is probably a holobaramin.

Gillespie, A.K. 2007. Diversity and systematics of marsupial lions from the Riversleigh World Heritage Area and the evolution of the Thylacoleonidae. Ph.D. Dissertation. Sydney, Australia: University of New South Wales.
Characters: Craniodental



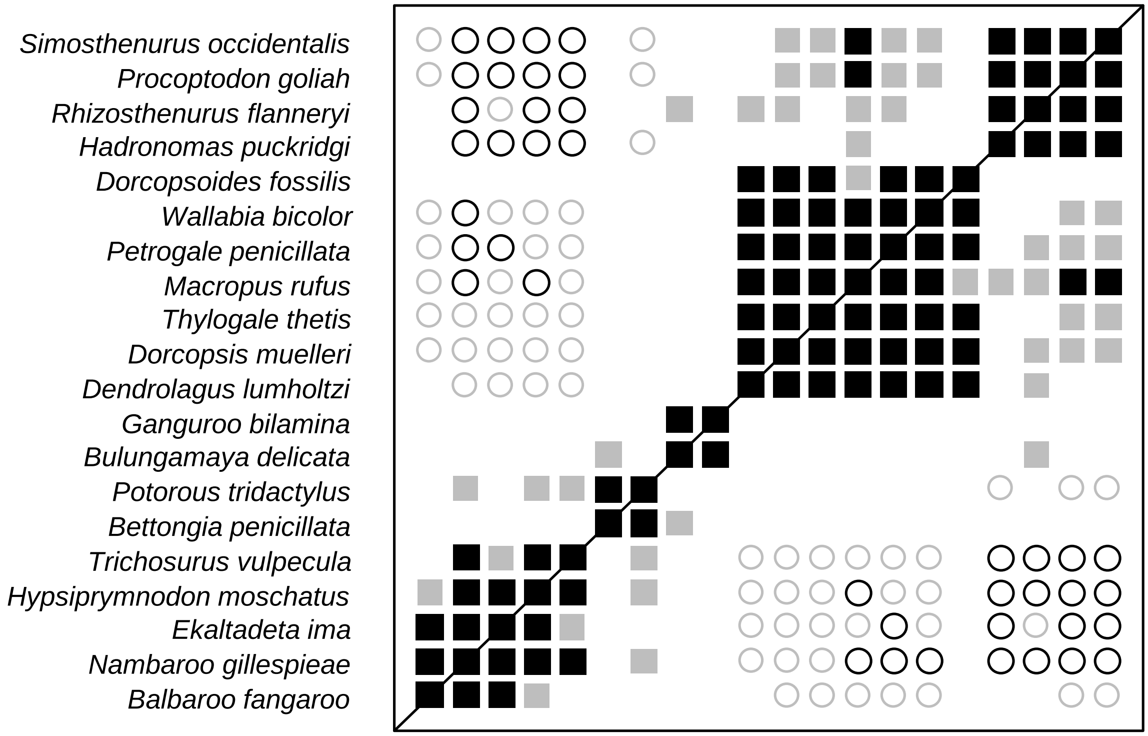


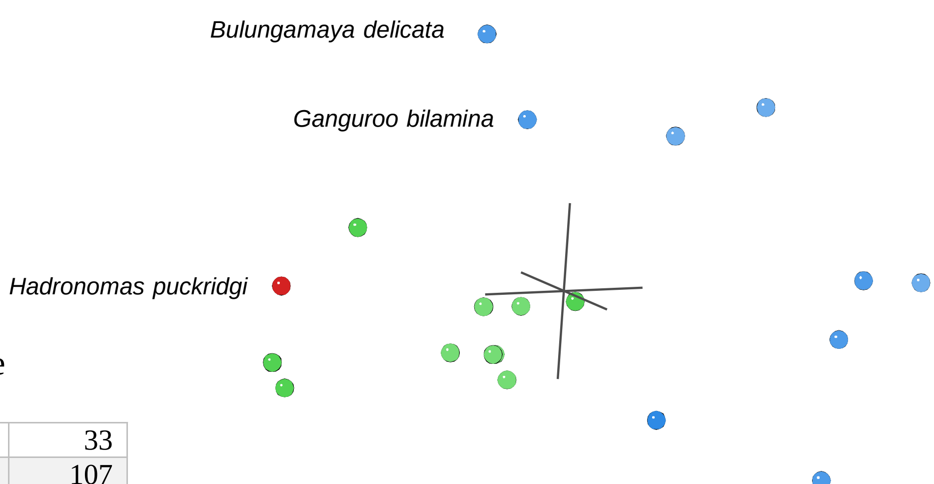
Order Diprotodontia
Family Thylacoleonidae

Published taxa	17
Published characters	72
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	12
Characters used for calculations	51
Median bootstrap value	89
F_{90}	0.47
Stress of 3D MDS	0.12
k_{min}	6
Conclusion	HB?

Notes: This dataset comes from chapter 11 of Gillespie's dissertation. The BDC shows what appear to be four groups of thylacoleonids all negatively correlated with the outgroup taxa but with little evidence of positive correlation with each other. The MDS reveals an arc of thylacoleonid taxa surrounding a tight cluster of outgroup taxa. The curvilinear distribution of thylacoleonid taxa might account for the poor intrafamilial BDC results. Hence we may provisionally accept Thylacoleonidae as a holobaramin.

Bates, H., K.J. Travouillon, B. Cooke, R.M.D. Beck, S.J. Hand, and M. Archer. 2014. Three new Miocene species of musky rat-kangaroos (Hypsiprymnodontidae, Macropodoidea): description, phylogenetics, and paleoecology. *Journal of Vertebrate Paleontology* 34:383-396.
Characters: Craniodental





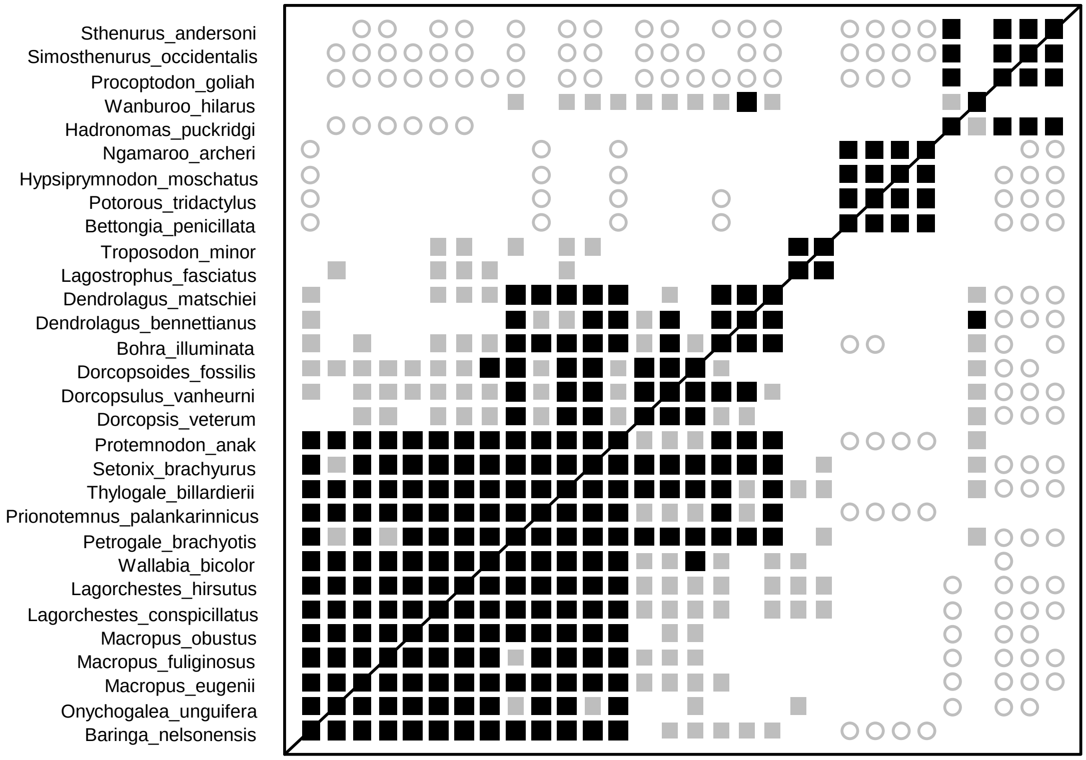
Order Diprotodontia
Family Hypsiprymnodontidae

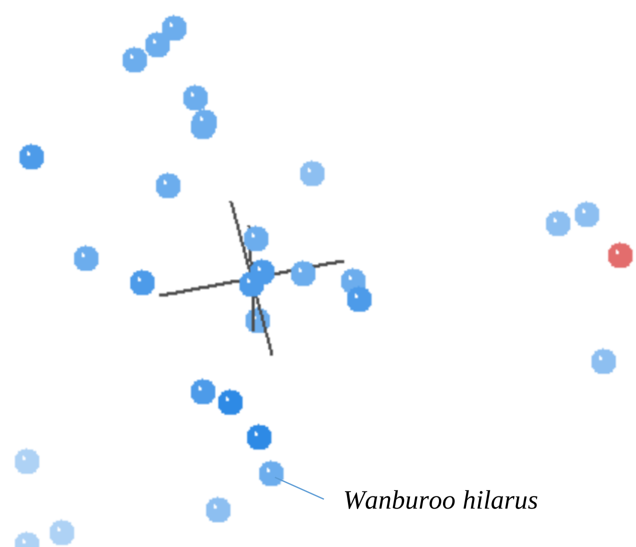
Published taxa	33
Published characters	107
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	20
Characters used for calculations	93
Median bootstrap value	84
F_{90}	0.36
Stress of 3D MDS	0.12
k_{min}	5
Conclusion	HB

Red: outgroup
Green: Macropodidae
Blue: Hypsiprymnodontidae

Notes: MDS reveals a disperse cluster of ingroup taxa, but BDC supports recognizing a discontinuity between ingroup and outgroup. There is only one taxon pair with significant, positive BDC between the Macropodidae and Hypsiprymnodontidae: *Rhizosthenurus flanneryi* and *Bulungamaya delicata* respectively. Since the bootstrap value for that correlation is only 79% and the MDS reveals that *Bulungamaya* is an outlier from the hypsiprymnodontids and not adjacent to the macropodids, we may consider that correlation spurious. Hypsiprymnodontidae is probably a holobaramin.

Prideaux, G.J. and R.H. Tedford. 2012. *Tjukuru wellsi*, gen. et sp. nov., a lagostrophine kangaroo (Diprotodontia, Macropodidae) from the Pliocene (Tirarian) of northern South Australia. *Journal of Vertebrate Paleontology* 32:717-721.
Characters: Craniodental and postcranial



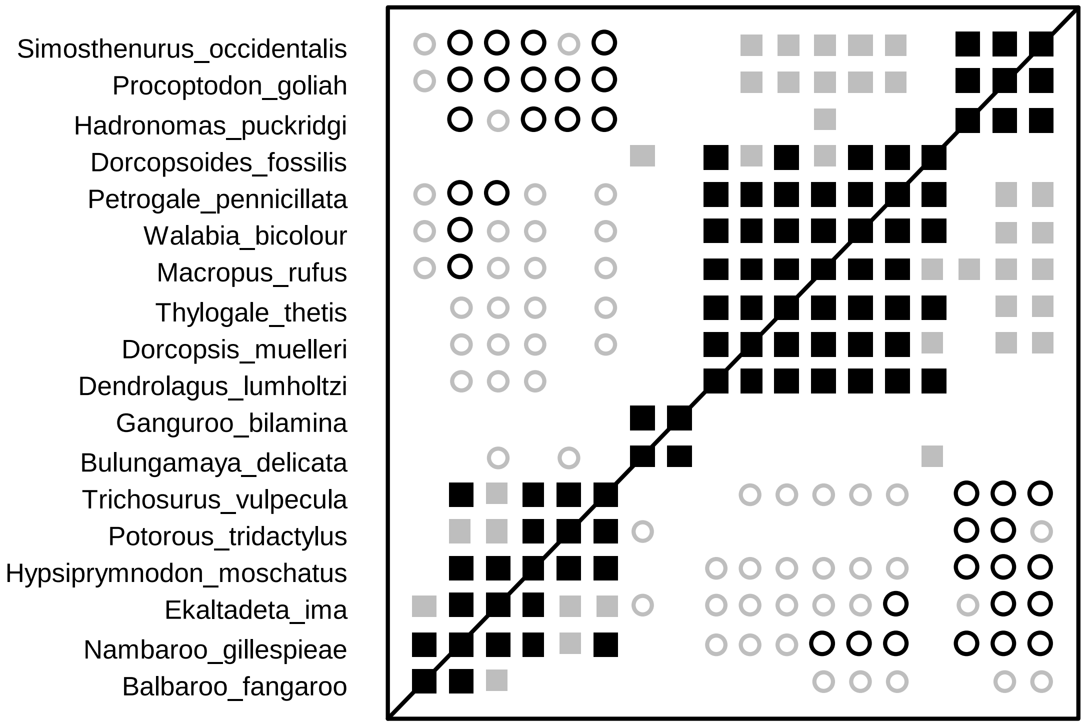


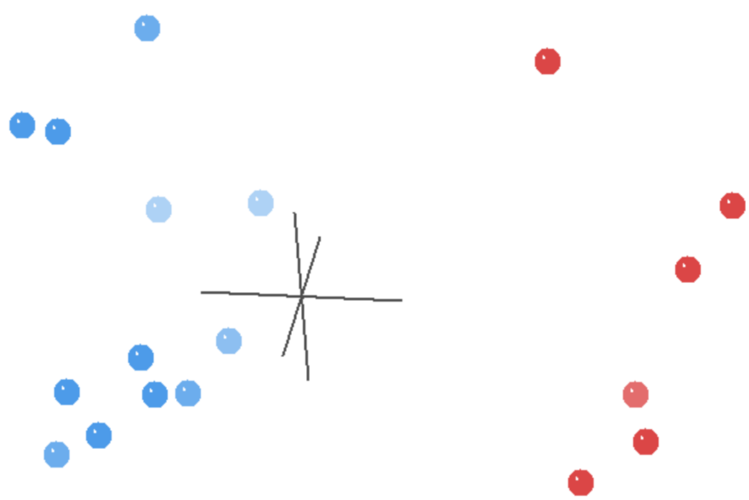
Order Diprotodontia
Family Macropodidae

Published taxa	36
Published characters	83
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	30
Characters used for calculations	80
Median bootstrap value	81
F_{90}	0.34
Stress of 3D MDS	0.18
k_{min}	6
Conclusion	HB?

Notes: The outgroup indicated in the MDS results is only the hypsiprymnodontid *Hypsiprymnodon moschatus*. Other non-macropodid taxa include the potoroids *Bettongia* and *Potorous*.
The BDC results indicate a clear separation between macropodids and the three outgroup taxa. Also, BDC shows positive BDC between stem macropodoid *Ngamaroo* and the outgroup taxa and negative BDC between *Ngamaroo* and the ingroup. Macropodoid *Wanburoo* appears to correlate with the outgroup and ingroup taxa, but the MDS results reveal that *Wanburoo* is not actually part of the outgroup cluster. Instead, it appears to be part of the Macropodidae holobaramin.

Kear, B.P., B.N. Cooke, M. Archer, and T.F. Flannery. 2007. Implications of a new species of the Oligo-Miocene kangaroo (Marsupialia: Macropodoidea) *Nambaroo*, from the Riversleigh World Heritage Area, Queensland, Australia. *Journal of Paleontology* 81:1147-1167.
Characters: Craniodental and postcranial



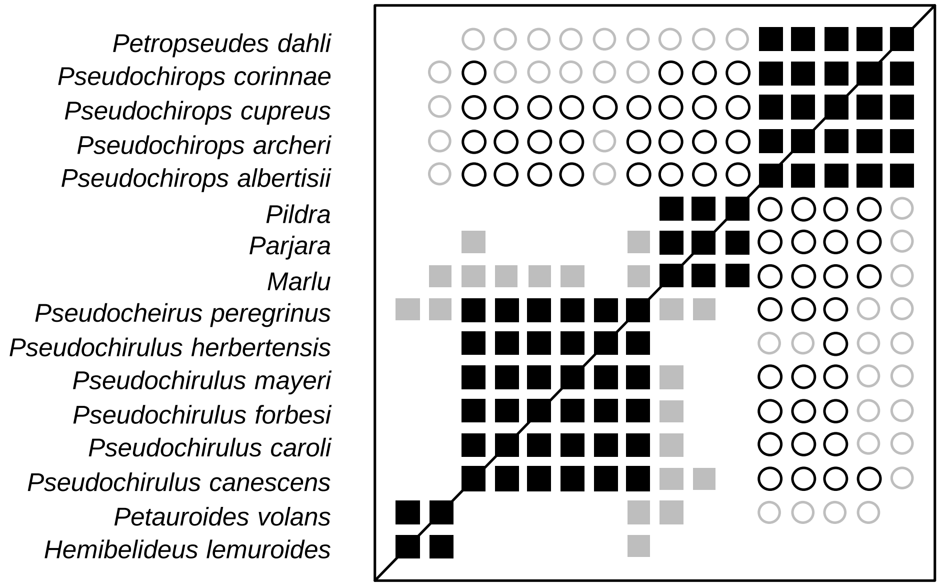


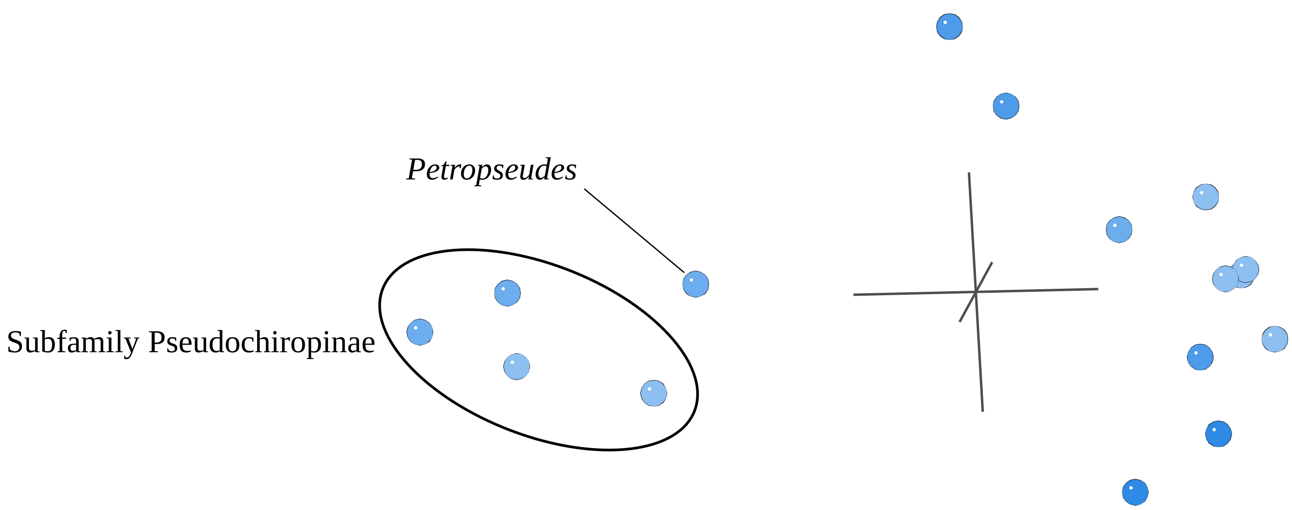
Order Diprotodontia
Family Macropodidae

Published taxa	25
Published characters	104
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	18
Characters used for calculations	85
Median bootstrap value	83
F_{90}	0.34
Stress of 3D MDS	0.15
k_{min}	6
Conclusion	HB

Notes: This second macropodid dataset is included because it contains fewer taxa than the previous Prideaux and Tedford dataset but more characters. In this case, the outgroups and macropodids are definitely separated in both BDC and MDS results, supporting the inference that Macropodidae is a holobaramin.

Springer, M.S. 1993. Phylogeny and rates of character evolution among ringtail possums (Pseudocheiridae, Marsupialia). *Australian Journal of Zoology* 41:273-291.
Characters: Craniodental



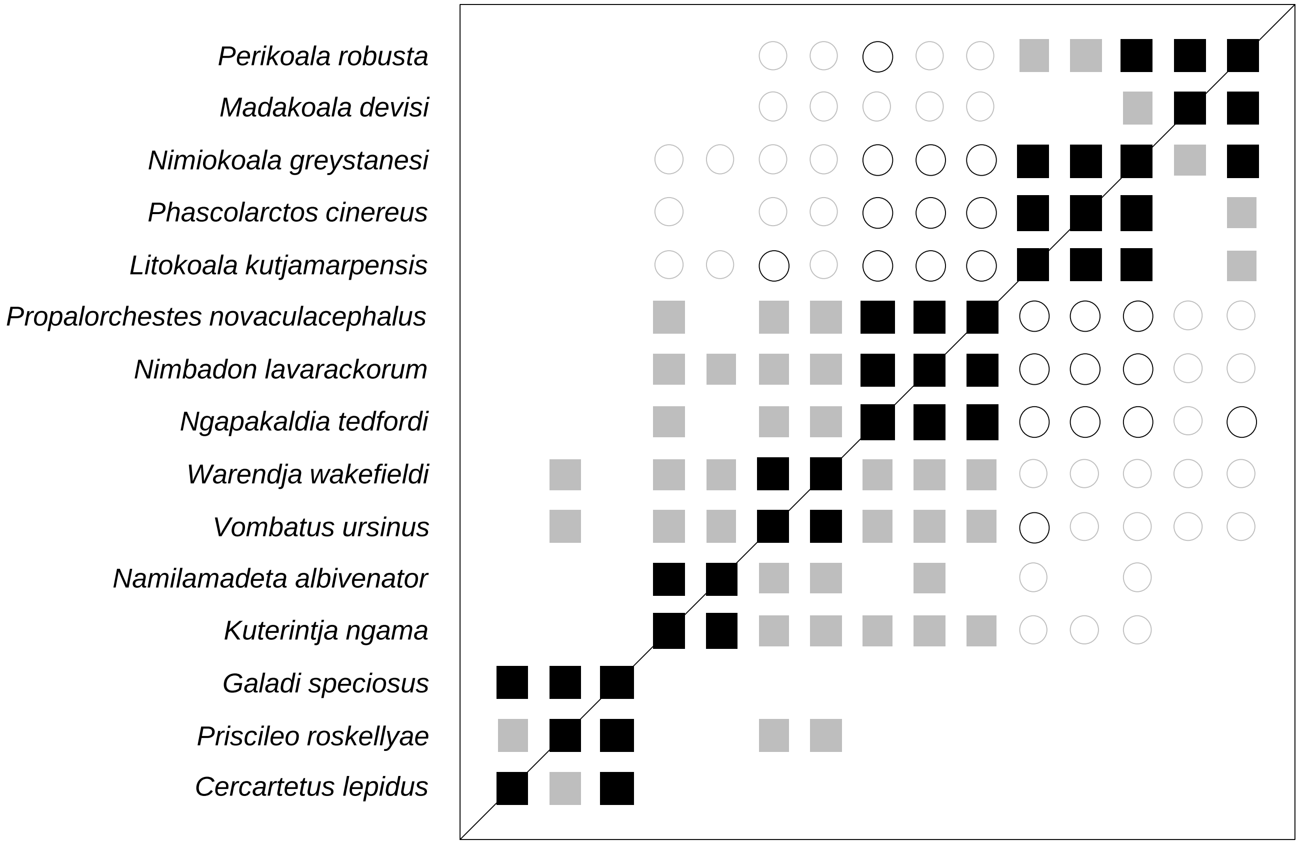


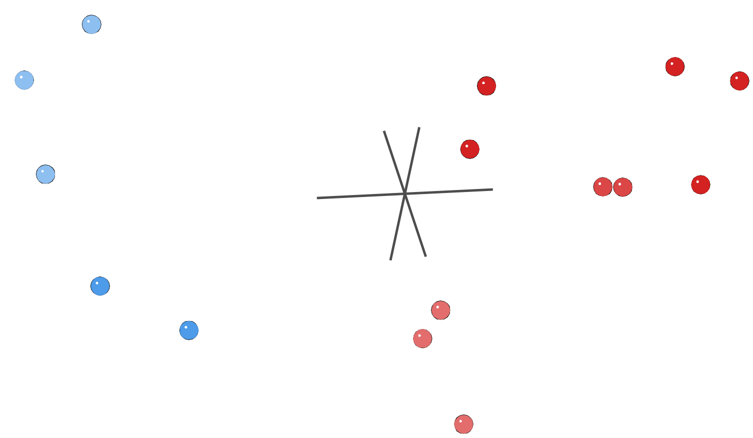
Order Diprotodontia
Family Pseudocheiridae

Published taxa	16
Published characters	56
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	16
Characters used for calculations	56
Median bootstrap value	87.5
F_{90}	0.46
Stress of 3D MDS	0.04
k_{min}	4
Conclusion	HB

Notes: Two holobaramins: Subfamily Pseudochiropinae + *Petropseudes*, and all other taxa.

Black, K.H., M. Archer, and S.J. Hand. 2012. New Tertiary koala (Marsupialia, Phascolarctidae) from Riversleigh, Australia, with a revision of phascolarctid phylogenetics, paleoecology, and paleobiodiversity. *Journal of Vertebrate Paleontology* 32:125-138.
Characters: Craniodental



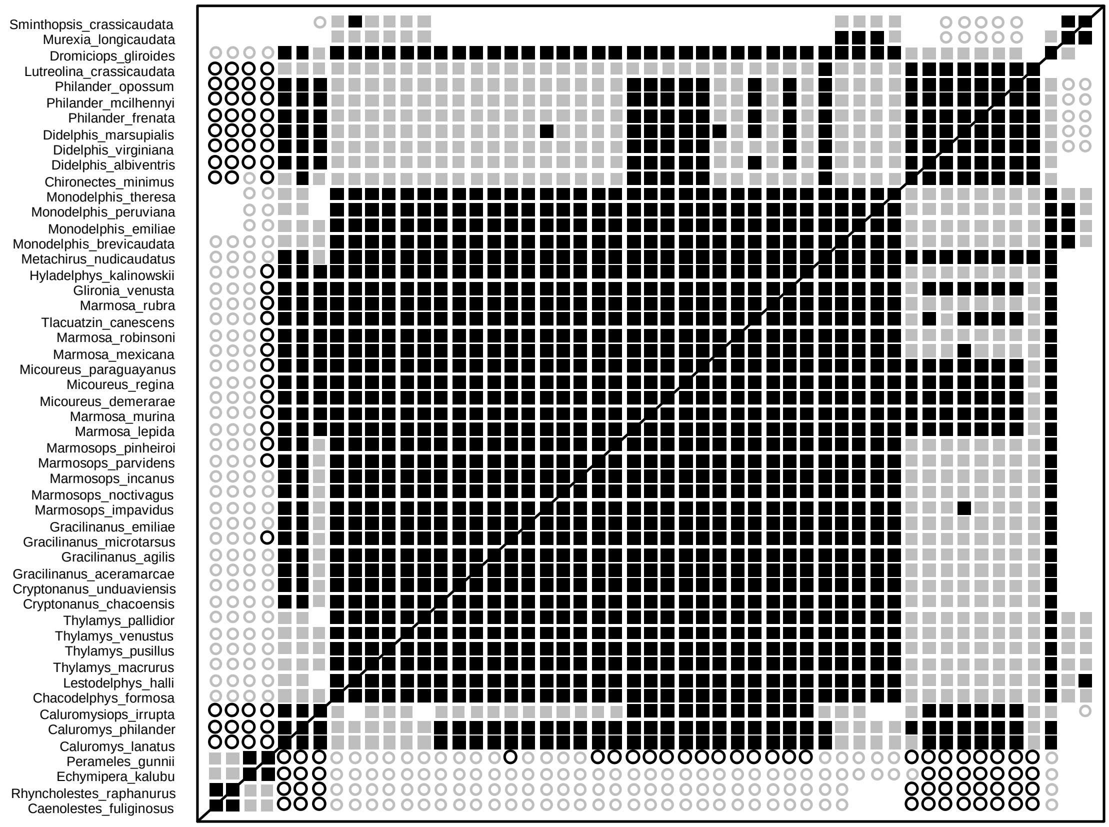


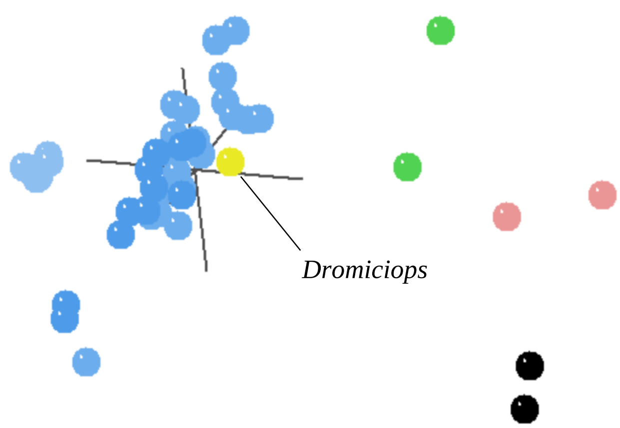
Order Diprotodontia
Family Phascolarctidae

Published taxa	19
Published characters	71
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	15
Characters used for calculations	50
Median bootstrap value	86
F_{90}	0.38
Stress of 3D MDS	0.1
k_{min}	6
Conclusion	HB

Notes: Phascolarctidae is a holobaramin.

Voss, R.S. and S.A. Jansa. 2009. Phylogenetic relationships and classification of didelphid marsupials, an extant radiation of New World metatherian mammals. *Bulletin of the American Museum of Natural History* 322:1-177.
Characters: External morphology, craniodental, karyotype





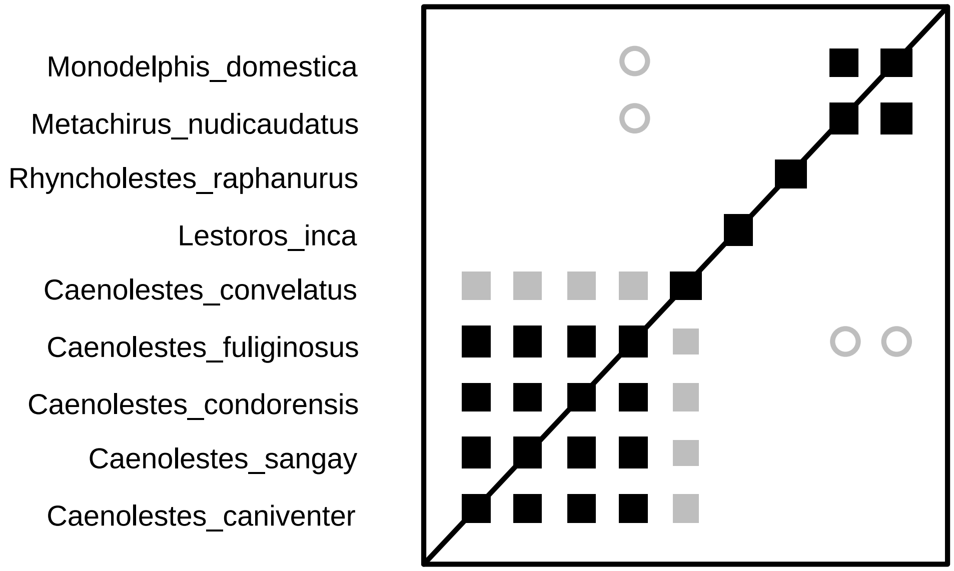
Order Didelphimorphia
Family Didelphidae

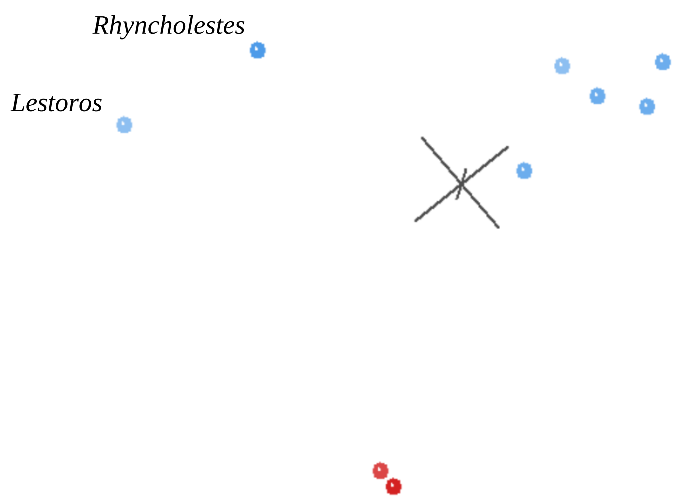
Published taxa	51
Published characters	129
Character relevance	0.95
Taxic relevance	0
Taxa used for calculations	51
Characters used for calculations	115
Median bootstrap value	97
F_{90}	0.61
Stress of 3D MDS	0.21
k_{min}	8
Conclusion	HB?

Blue: Didelphidae
Yellow: Microbiotheriidae
Green: Dasyuridae
Red: Peramelidae
Black: Caenolestidae

Notes: BDC supports inference of discontinuity between two groups: 1. Peramelidae + Caenolestidae and 2. Didelphidae + Microbiotheriidae + Dasyuridae. MDS supports including microbiotheriid *Dromiciops* in Didelphidae, but dasyurids are more distant. Either Didelphidae + *Dromiciops* or Didelphidae + *Dromiciops* + Dasyuridae is a holobaramin.

Ojala-Barbour, R., C.M. Pinto, M.J. Brito V.L. Albuja T.E. Lee Jr, and B.D. Patterson. 2013. A new species of shrew-opossum (Paucituberculata: Caenolestidae) with a phylogeny of extant caenolestids. *Journal of Mammalogy* 94:967-982.
Characters: External morphology, craniodental



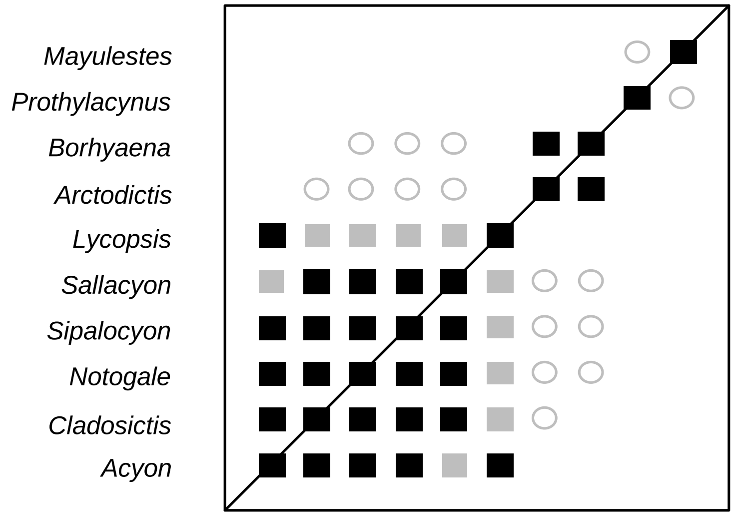


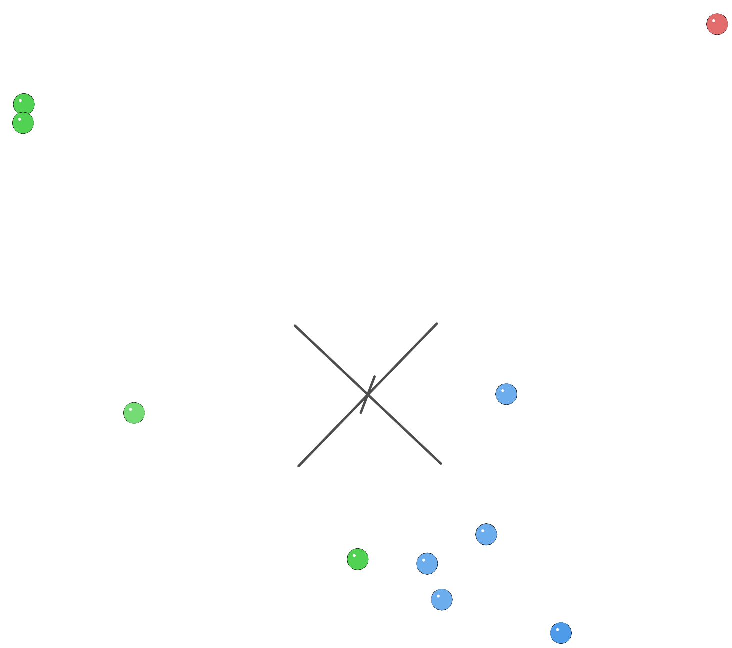
Order Paucituberculata
Family Caenolestidae

Published taxa	9
Published characters	33
Character relevance	0.95
Taxic relevance	0
Taxa used for calculations	9
Characters used for calculations	33
Median bootstrap value	94
F_{90}	0.56
Stress of 3D MDS	0.08
k_{min}	5
Conclusion	MB

Notes: BDC correlations between *Caenolestes* species suggests that at minimum, *Caenolestes* is a monobaramin. There is no evidence that would suggest continuity between the three caenolestid genera or discontinuity of any kind.

Forasiepi, A.M., M.R. Sánchez-Villagra, F.J. Goin, M. Takai, N. Shigehara, and R.F. Kay. 2006. A new species of Hathliacynidae (Metatheria, Sparassodonta) from the middle Miocene of Quebrada Honda, Bolivia. *Journal of Vertebrate Paleontology* 26:670-684.
Characters: Craniodental





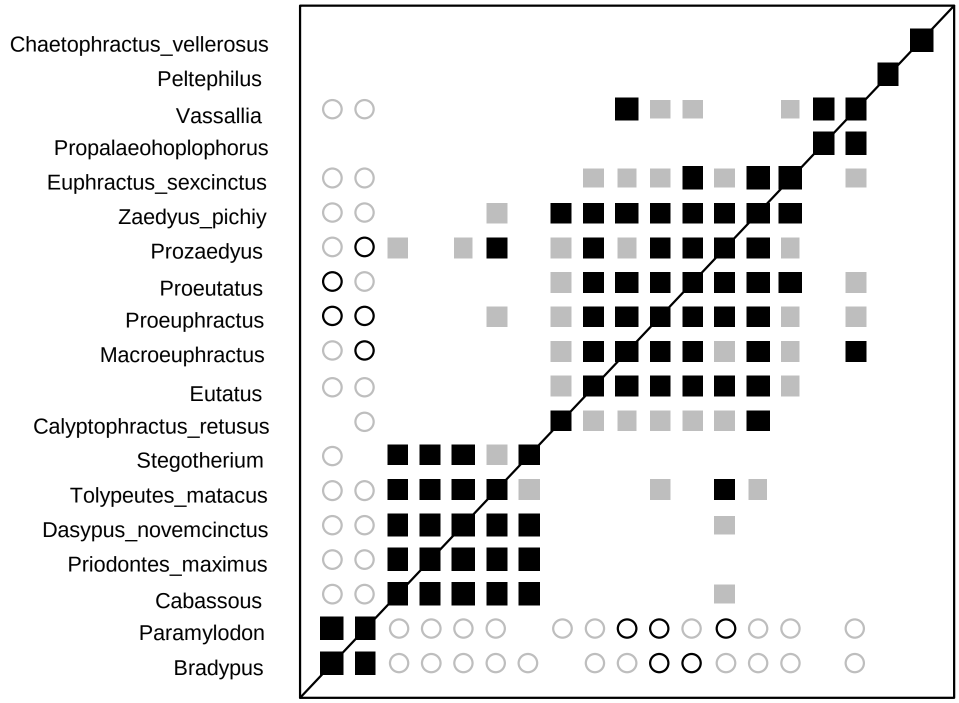
Order Sparassodonta
Family Hathliacynidae

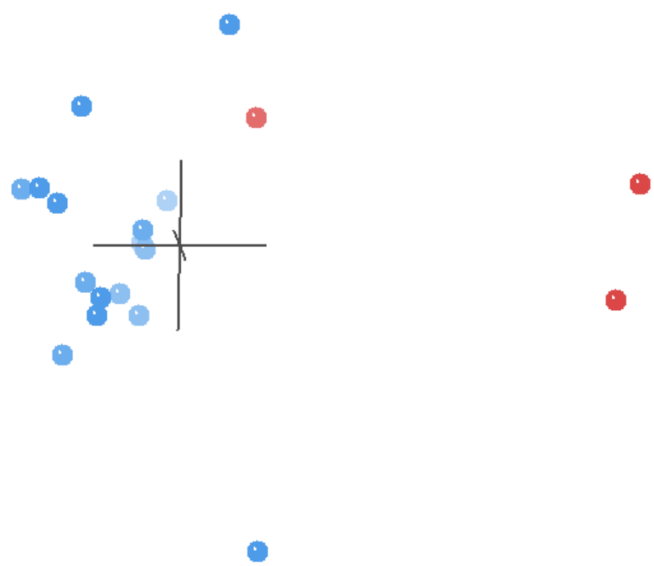
Published taxa	10
Published characters	47
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	10
Characters used for calculations	39
Median bootstrap value	89
F_{90}	0.4
Stress of 3D MDS	0.08
k_{min}	3
Conclusion	HB?

Red: outgroup
Green: Borhyaenidae
Blue: Hathliacynidae

Notes: Hathliacynidae + *Lycopsis* could be a holobaramin; evidence of discontinuity has poor bootstrap values.

Herrera, C.M., J.E. Powell, G.I. Esteban, and C. del Papa. 2017. A new Eocene dasypodid with caniniforms (Mammalia, Xenarthra, Cingulata) from northwest Argentina. *Journal of Mammalian Evolution* 24:275-288.
Characters: Craniodental and postcranial



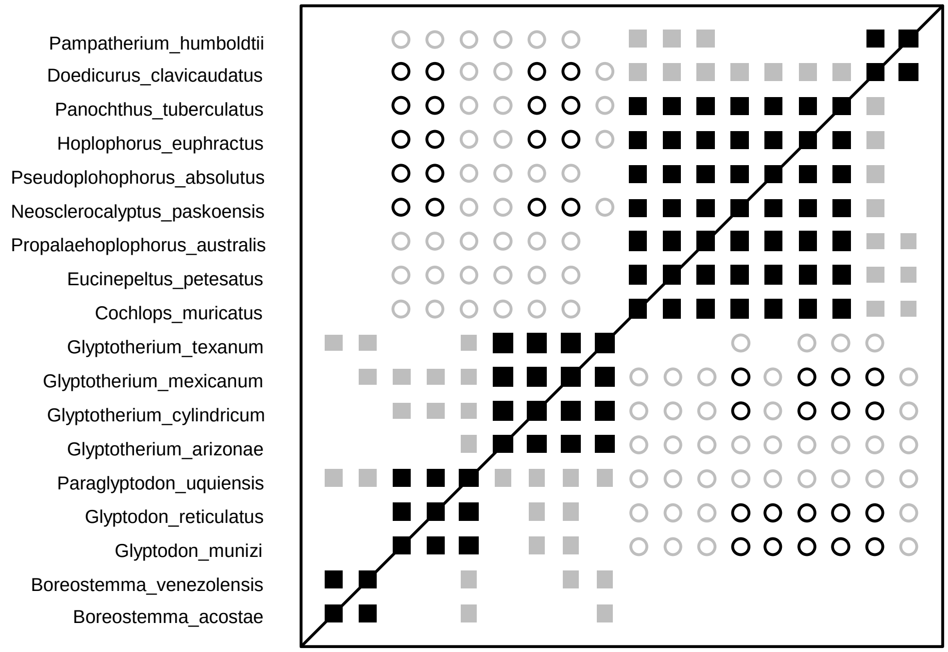


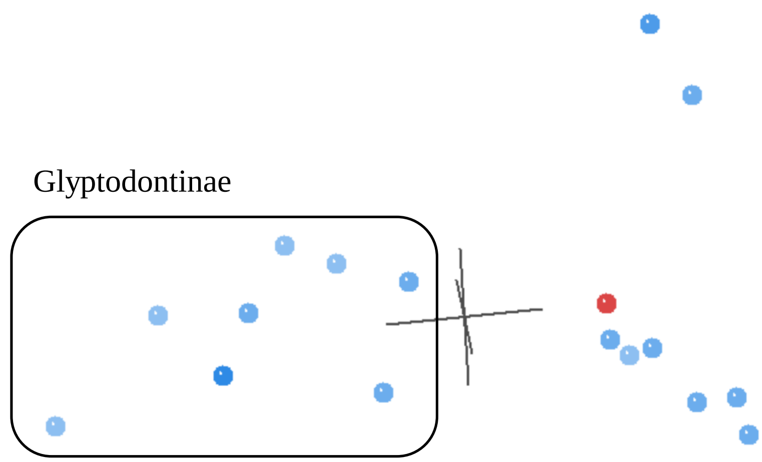
Order Cingulata
Family Dasypodidae

Published taxa	22
Published characters	144
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	19
Characters used for calculations	106
Median bootstrap value	94
F_{90}	0.58
Stress of 3D MDS	0.29
k_{min}	11
Conclusion	HB

Notes: Significant, negative BDC between two outgroup taxa and the ingroup taxa is widespread but has poor bootstrap values. Chlamyphorid *Peltephilus* clusters with the dasypodids in both BDC and MDS results. Dasypodidae + *Peltephilus* are a holobaramin. Dasypodid *Chaetophractis* appears to be separate from the holobaramin.

Zurita, A.E., L.R.G. Ruiz, A.J. Gómez-Cruz, and J.E. Arenas-Mosquera. 2013. The most complete known Neogene Glyptodontidae (Mammalia, Xenarthra, Cingulata) from northern South America: taxonomic, paleobiogeographic, and phylogenetic implications. *Journal of Vertebrate Paleontology* 33:696-708.
Characters: Cranial and postcranial



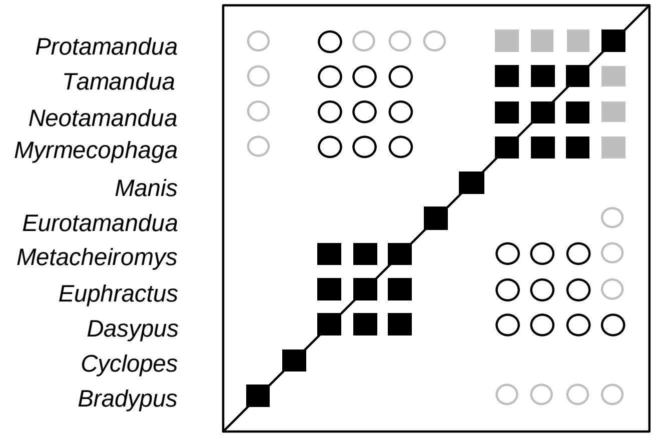


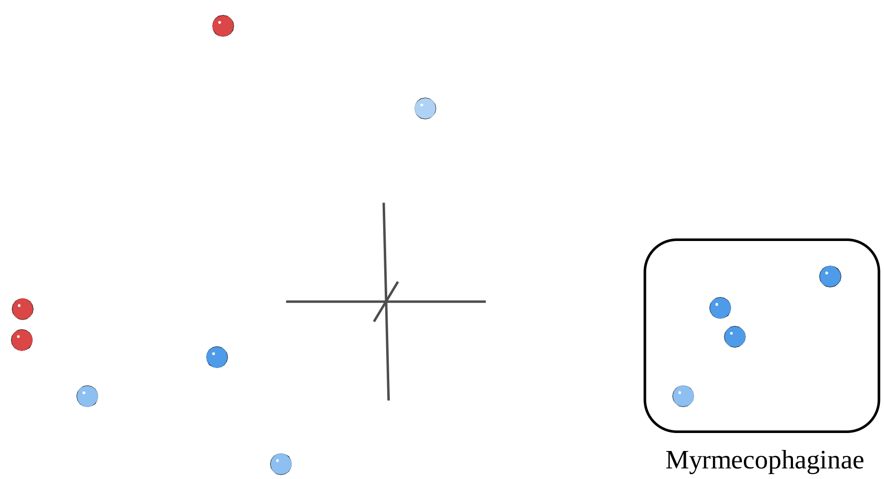
Order Cingulata
Family Glyptodontidae

Published taxa	18
Published characters	26
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	18
Characters used for calculations	23
Median bootstrap value	75
F_{90}	0.31
Stress of 3D MDS	0.13
k_{min}	4
Conclusion	HB

Notes: Subfamily Glyptodontinae is well-separated in both BDC and MDS analyses. Glyptodontinae is probably a holobaramin.

Gaudin, T.J. and D.G. Branham. 1998. The phylogeny of the Myrmecophagidae (Mammalia, Xenarthra, Vermilingua) and the relationship of *Eurotamandua* to the Vermilingua. *Journal of Mammalian Evolution* 5:237-265.
Characters: Cranial and postcranial



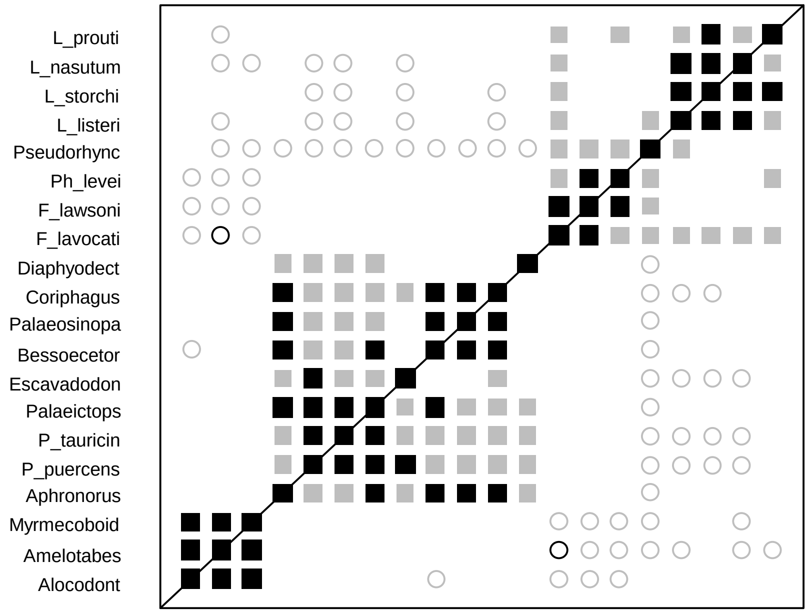


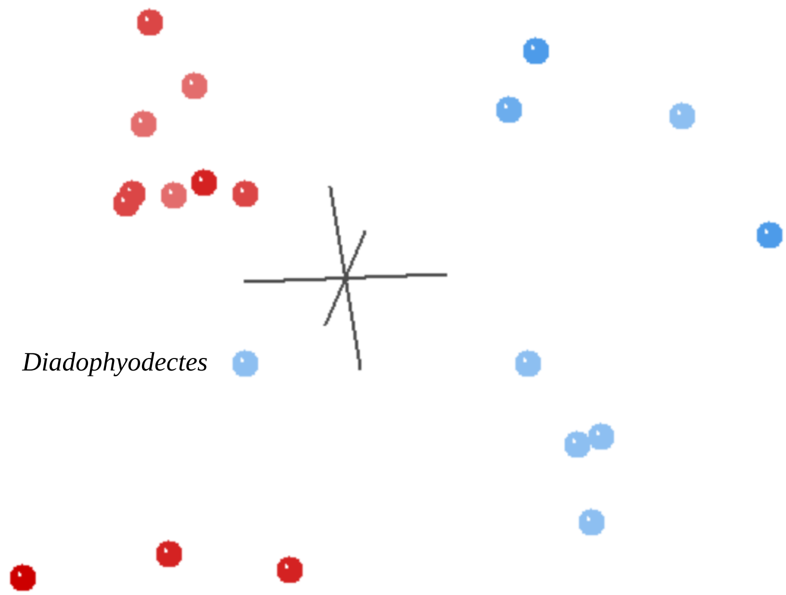
Order Pilosa
Family Myrmecophagidae

Published taxa	12
Published characters	107
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	11
Characters used for calculations	88
Median bootstrap value	92
F_{90}	0.58
Stress of 3D MDS	0.13
k_{min}	6
Conclusion	HB?

Notes: Both the MDS and BDC results appear to show a separation between the subfamily Myrmecophaginae (*Myrmecophaga*, *Neotamandua*, *Tamandua*, *Protamandua*) and all other taxa. Myrmecophaginae appears to be a holobaramin.

Hooker, J.J. 2013. Origin and evolution of the Pseudorhynchocyonidae, a European Paleogene family of insectivorous placental mammals. *Palaeontology* 56:807-835.
Characters: Craniodental



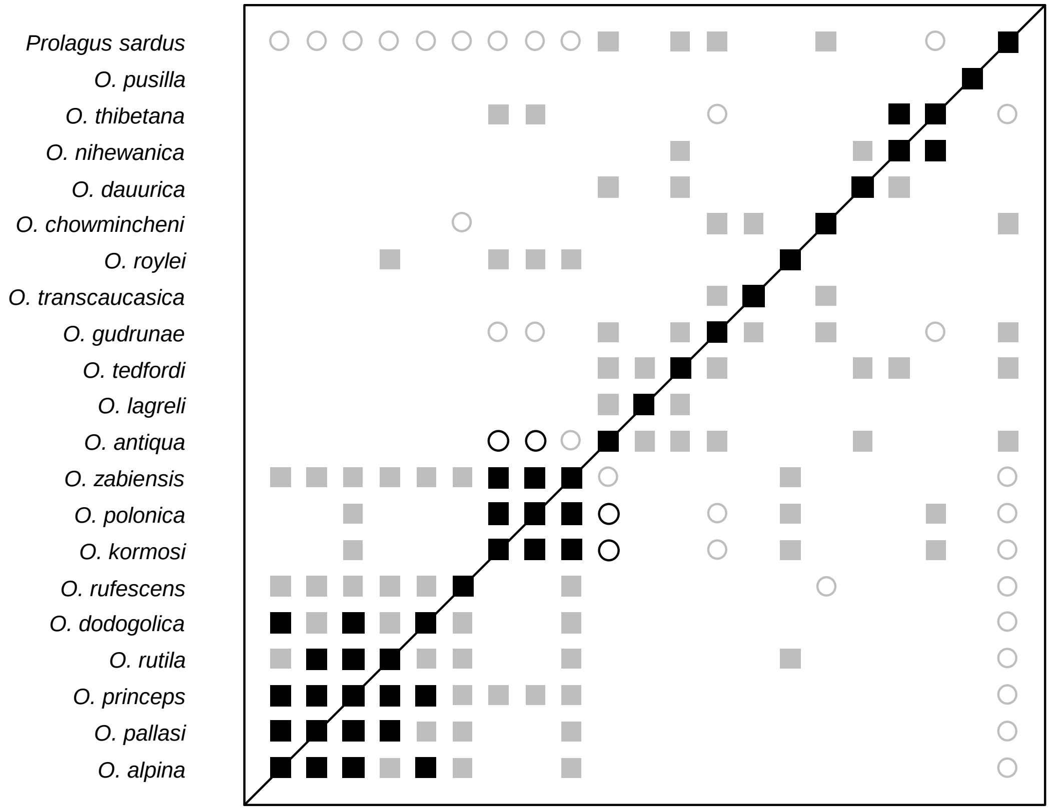


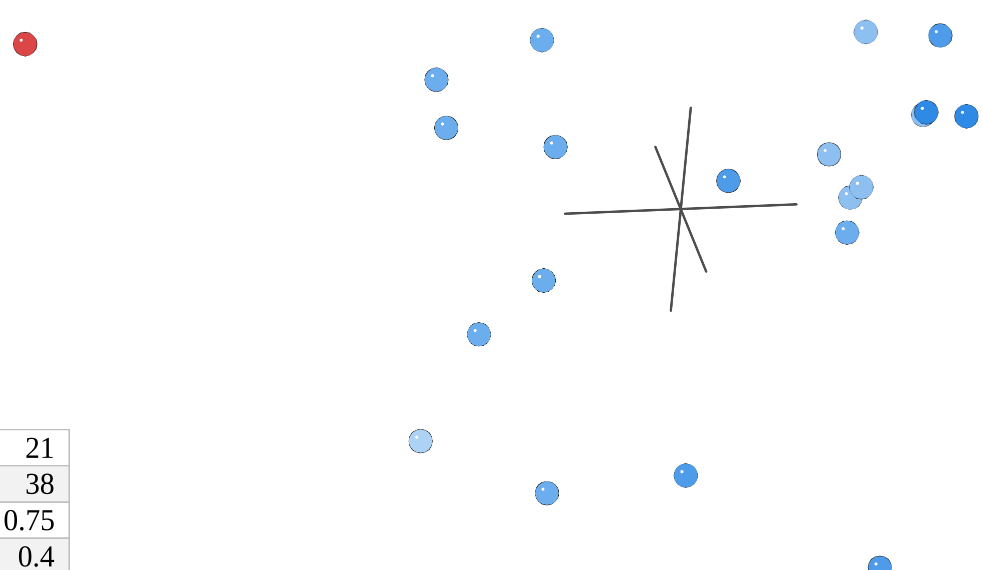
Order Leptictida
Family Pseudorhynchocyonidae

Published taxa	21
Published characters	56
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	21
Characters used for calculations	38
Median bootstrap value	78
F_{90}	0.12
Stress of 3D MDS	0.19
k_{min}	4
Conclusion	HB?

Notes: BDC reveals significant, negative BDC with poor bootstrap values, and the MDS shows a diffuse cluster of taxa. Nevertheless, the data support recognizing Pseudorhynchocyonidae as a provisional holobaramin. The position of *Diadophyodectes*, which clusters with the outgroup in MDS and BDC results, remains uncertain.

Fostowicz-Frelik, Ł., G.J. Frelik, and M. Gasparik. 2010. Morphological phylogeny of pikas (Lagomorpha: Ochotona), with a description of a new species from the Pliocene/Pleistocene transition of Hungary. *Proceedings of the Academy of Natural sciences of Philadelphia* 159:97-118.
Characters: Craniodental



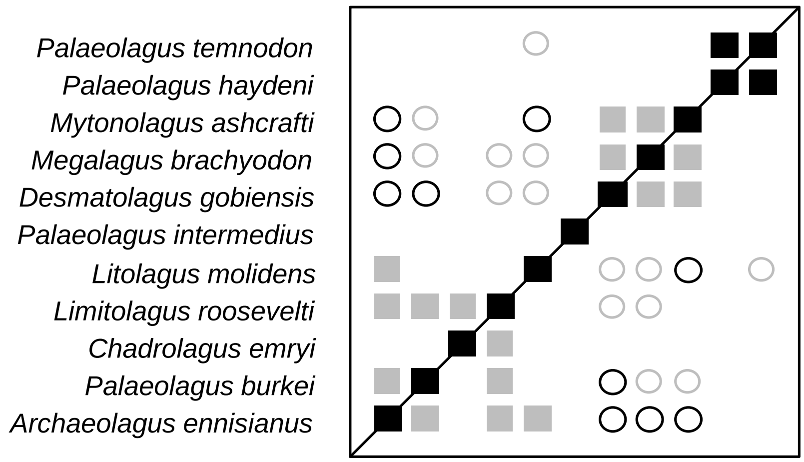


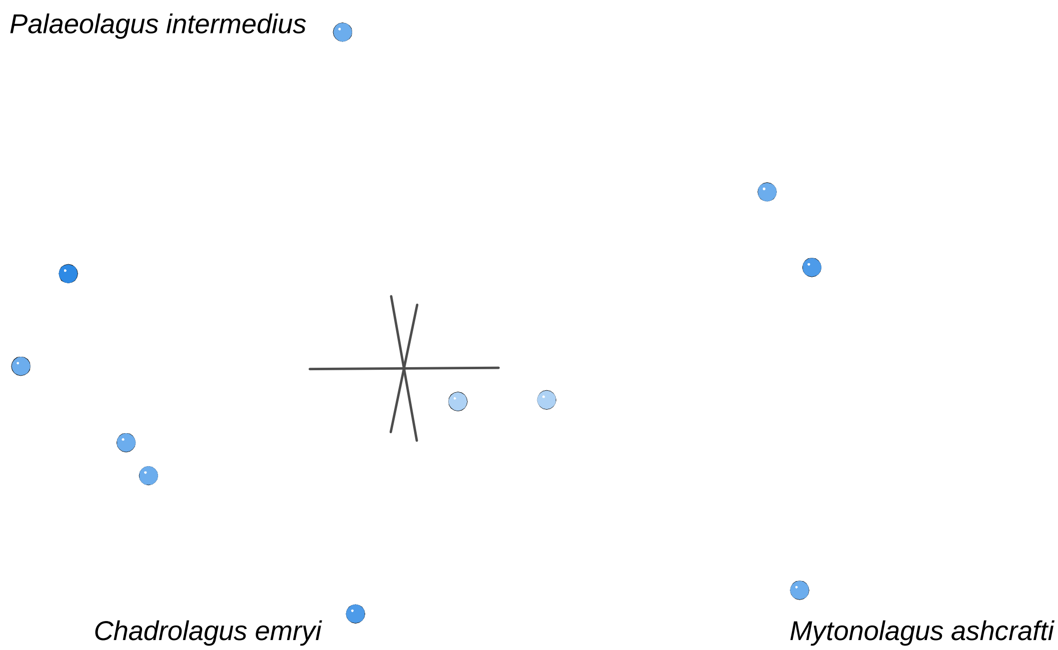
Order Lagomorpha
Family Ochotonidae

Published taxa	21
Published characters	38
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	21
Characters used for calculations	24
Median bootstrap value	69
F_{90}	0.06
Stress of 3D MDS	0.22
k_{min}	6
Conclusion	Inc

Notes: In BDC results, taxic groups are not evident and bootstrap values are very poor. MDS suggests Ochotonidae forms a cluster distinct from the one outgroup taxon.

Fostowicz-Frelik, Ł. 2013. Reassessment of *Chadrolagus* and *Litolagus* (Mammalia: Lagomorpha) and a new genus of North American Eocene lagomorph from Wyoming. *American Museum Novitates* 3773:1-76.
Characters: Craniodental



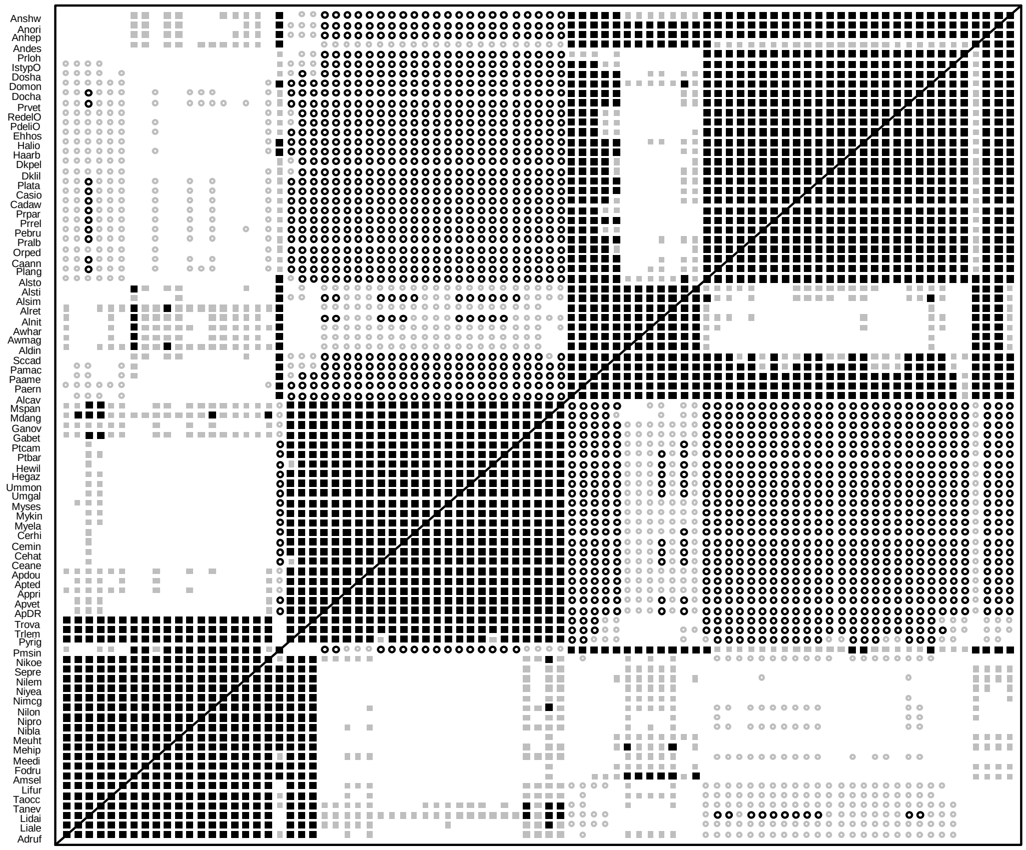


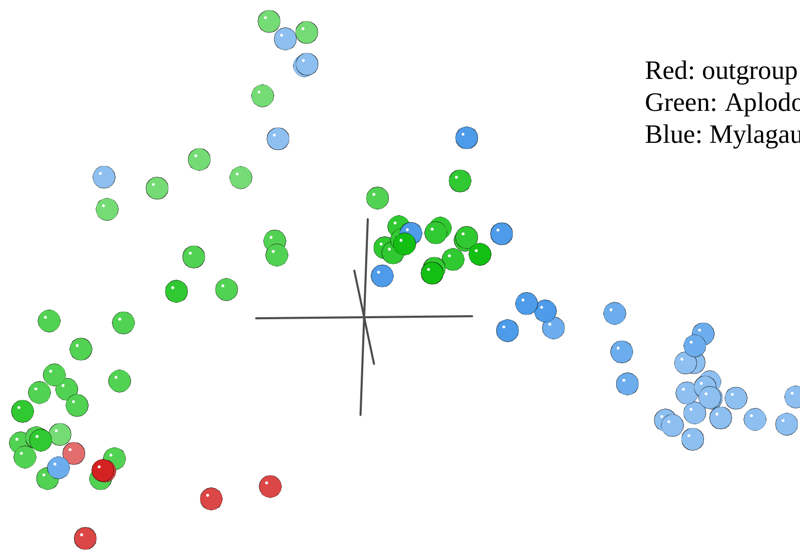
Order Lagomorpha
Family Leporidae

Published taxa	11
Published characters	44
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	11
Characters used for calculations	34
Median bootstrap value	89
F_{90}	0.49
Stress of 3D MDS	0.11
k_{min}	6
Conclusion	Inc

Notes: BDC results have poor bootstrap values, and MDS results indicate a highly diffuse cloud of taxa.

Hopkins, S.S. 2008. Phylogeny and evolutionary history of the Aplodontoidea (Mammalia: Rodentia). *Zoological Journal of the Linnean Society* 153:769-838.
Characters: Craniodental





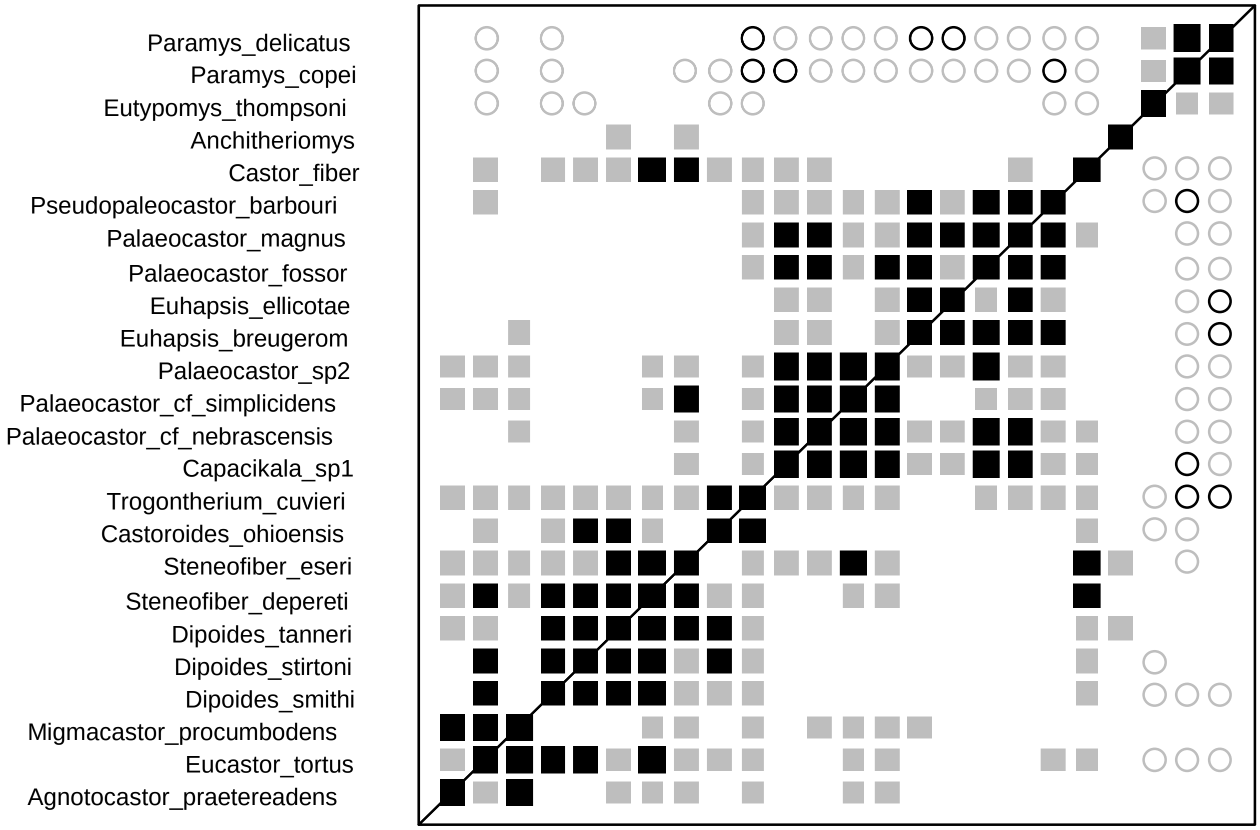
Red: outgroup
Green: Aplodontidae
Blue: Mylagaulidae

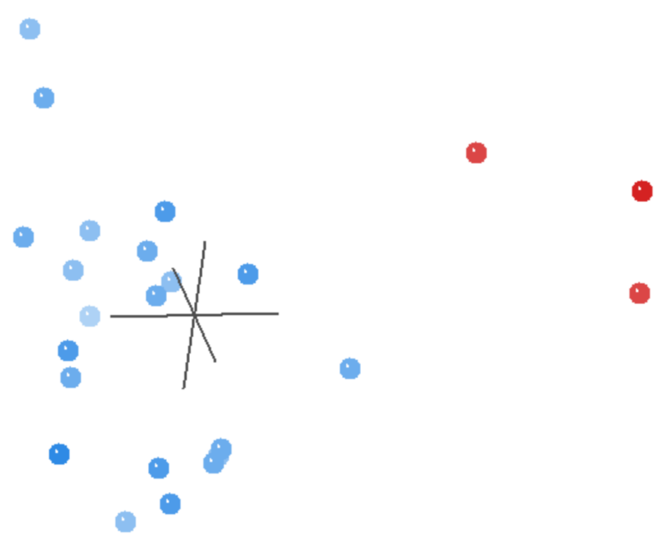
Order Rodentia
Family Aplodontidae

Published taxa	107
Published characters	249
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	85
Characters used for calculations	145
Median bootstrap value	95
F_{90}	0.54
Stress of 3D MDS	0.15
k_{min}	7
Conclusion	Inc

Notes: No evidence of discontinuity within superfamily Aplodontoidea. MDS reveals a cluster of taxa with families blending into one another.

Rybczynski, N. 2007. Castorid phylogenetics: implications for the evolution of swimming and tree-exploitation in beavers. *Journal of Mammalian Evolution* 14:1-35.
Characters: Cranial and postcranial



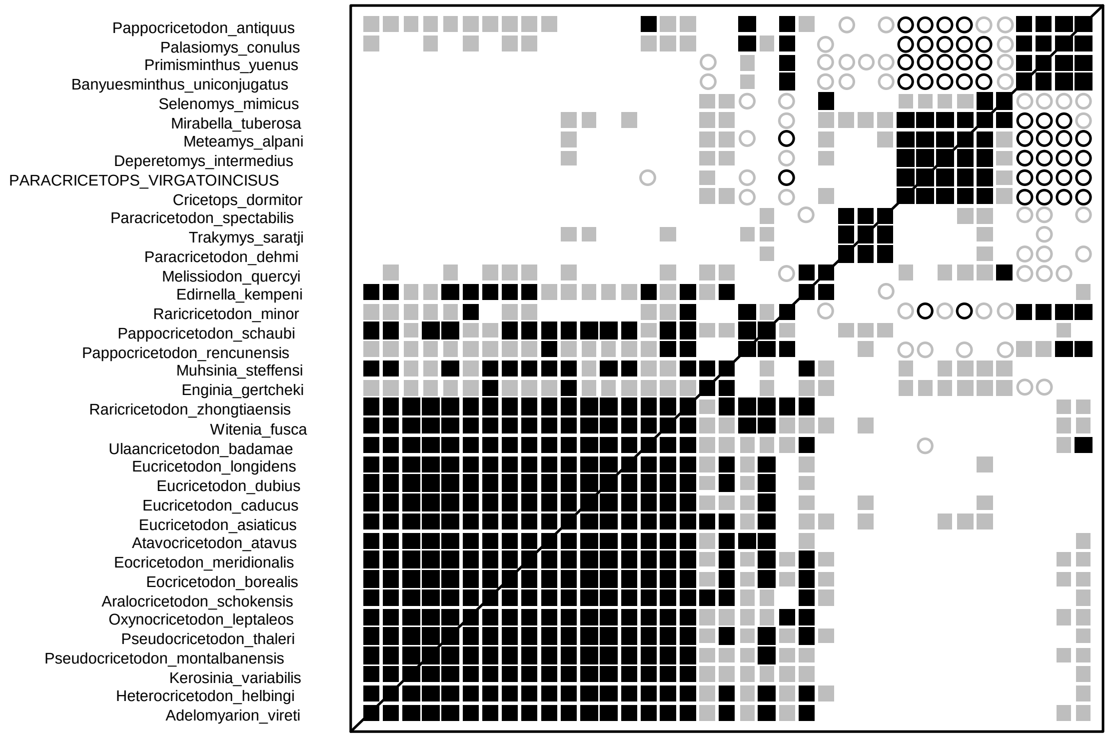


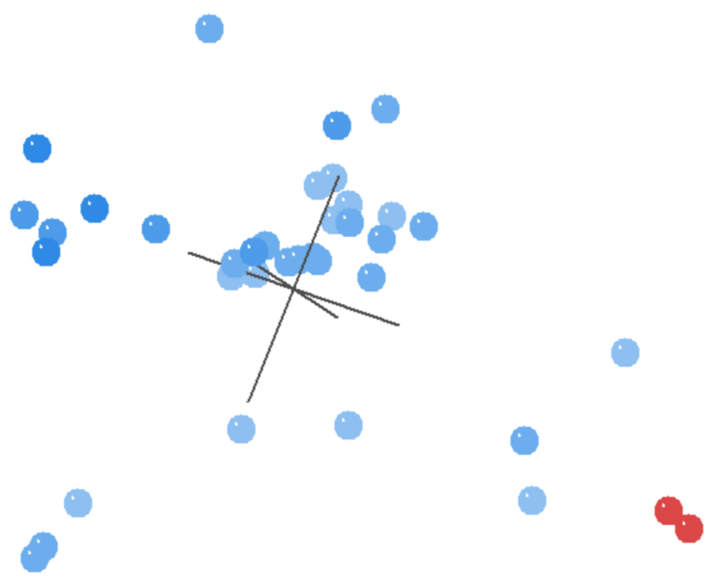
Order Rodentia
Family Castoridae

Published taxa	39
Published characters	88
Character relevance	0.75
Taxic relevance	0.5
Taxa used for calculations	24
Characters used for calculations	41
Median bootstrap value	78
F_{90}	0.16
Stress of 3D MDS	0.21
k_{min}	6
Conclusion	HB

Notes: Castorid taxa are well separated from the outgroup in both BDC and MDS results. Castoridae appears to be a holobaramin.

Maridet, O. and X. Ni. 2013. A new cricetid rodent from the early Oligocene of Yunnan, China, and its evolutionary implications for early Eurasian cricetids. *Journal of Vertebrate Paleontology* 33:185-194.
Characters: Craniodental



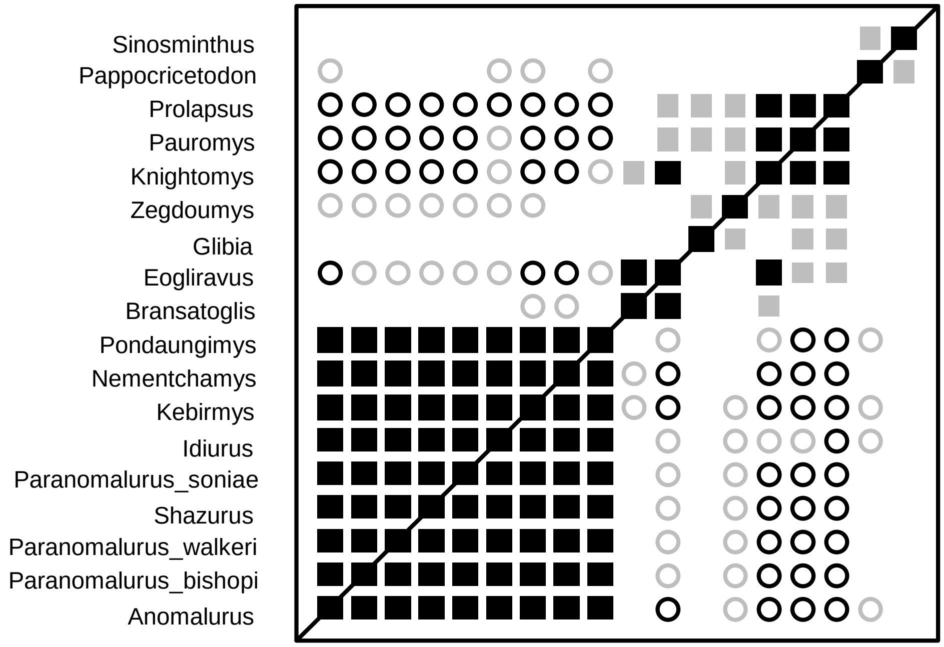


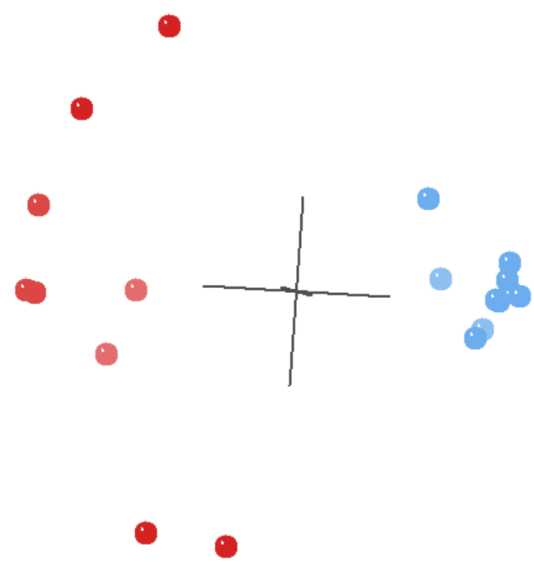
Order Rodentia
Family Cricetidae

Published taxa	37
Published characters	67
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	37
Characters used for calculations	50
Median bootstrap value	73
F_{90}	0.34
Stress of 3D MDS	0.18
k_{min}	5
Conclusion	Inc

Notes: No evidence of discontinuity in BDC or MDS results.

Sallam, H.M., E.R. Seiffert, E.L. Simons, and C. Brindley. 2010. A large-bodied anomaluroid rodent from the earliest late Eocene of Egypt: phylogenetic and biogeographic implications. *Journal of Vertebrate Paleontology* 30:1579-1593.
Characters: Craniodental



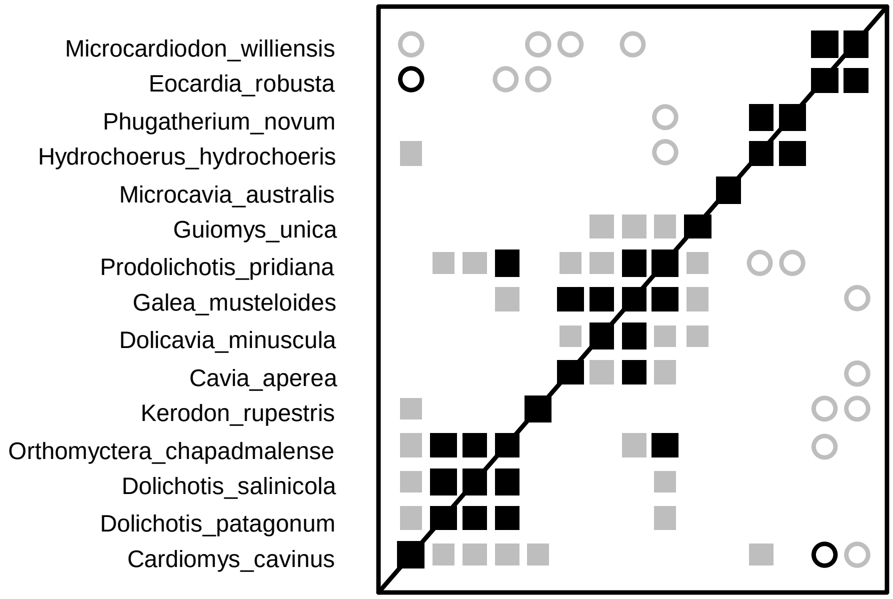


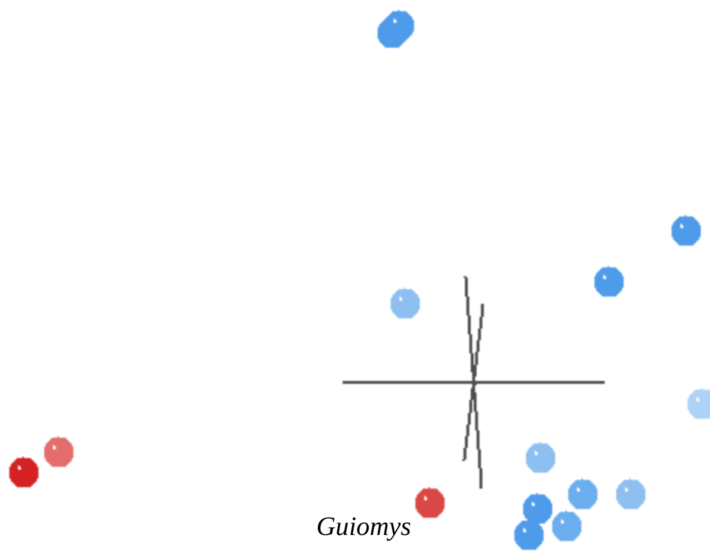
Order Rodentia
Family Anomaluridae

Published taxa	29
Published characters	99
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	18
Characters used for calculations	72
Median bootstrap value	89
F_{90}	0.48
Stress of 3D MDS	0.18
k_{min}	8
Conclusion	HB

Notes: Anomaluridae form a recognizable cluster in both BDC and MDS results. Anomaluridae is probably a holobaramin.

Pérez, M.E. and M.G. Vucetich. 2011. A new extinct genus of Cavioidea (Rodentia, Hystricognathi) from the Miocene of Patagonia (Argentina) and the evolution of cavioid mandibular morphology. *Journal of Mammalian Evolution* 18:163-183.
Characters: Craniodental



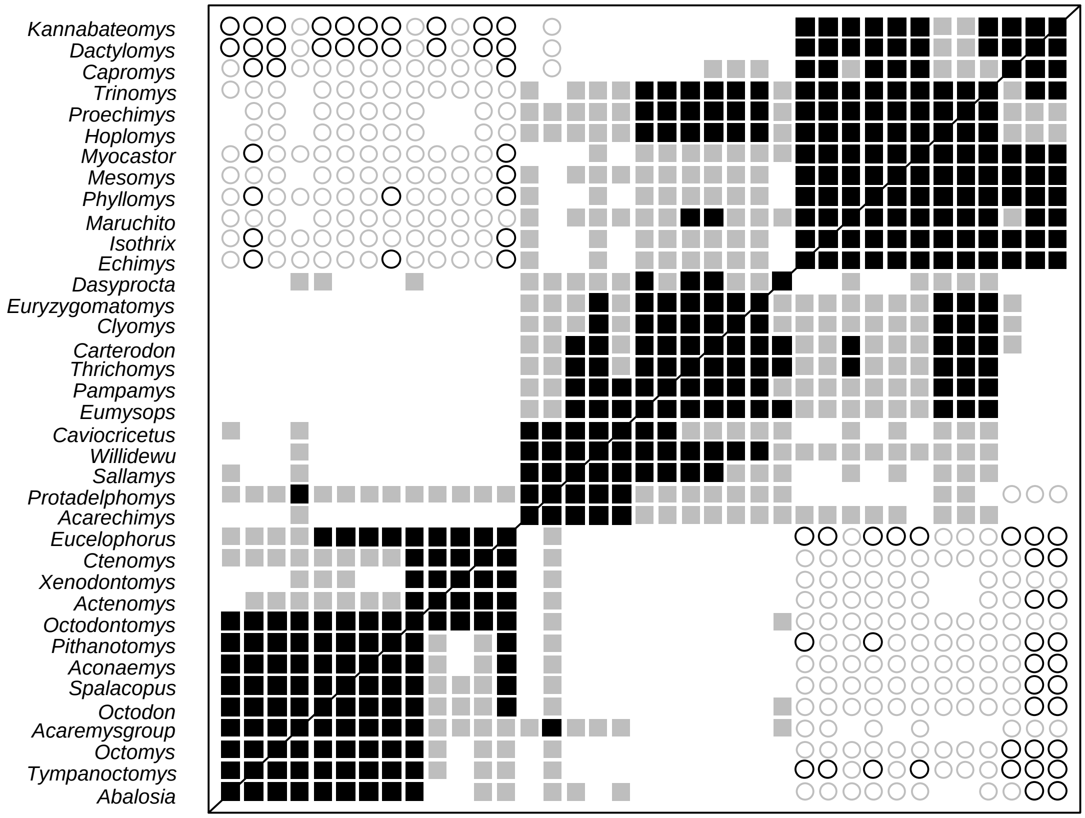


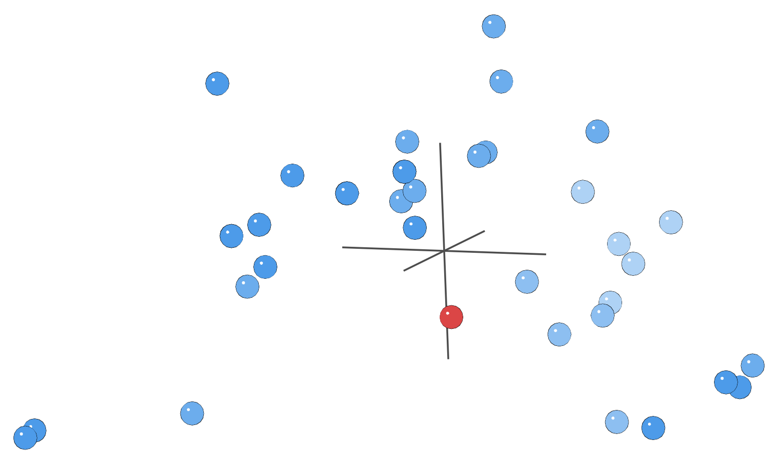
Order Rodentia
Family Caviidae

Published taxa	35
Published characters	89
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	15
Characters used for calculations	44
Median bootstrap value	74
F_{90}	0.1
Stress of 3D MDS	0.13
k_{min}	5
Conclusion	HB?

Notes: Caviidae + *Guiomys* might be a holobaramin. BDC evidence is weak but MDS seems to support a discontinuity.

Verzi, D.H., A.I. Olivares, and C.C. Morgan. 2013. Phylogeny and evolutionary patterns of South American octodontoid rodents. *Acta Palaeontologica Polonica* 59:757-769.
Characters: Craniodental



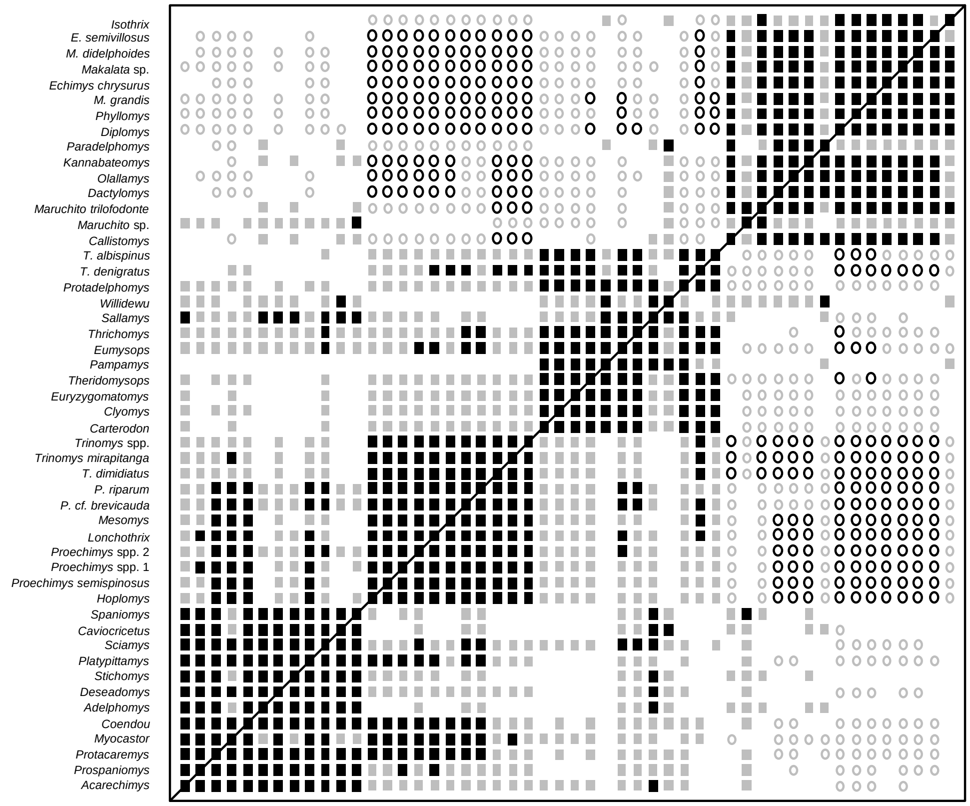


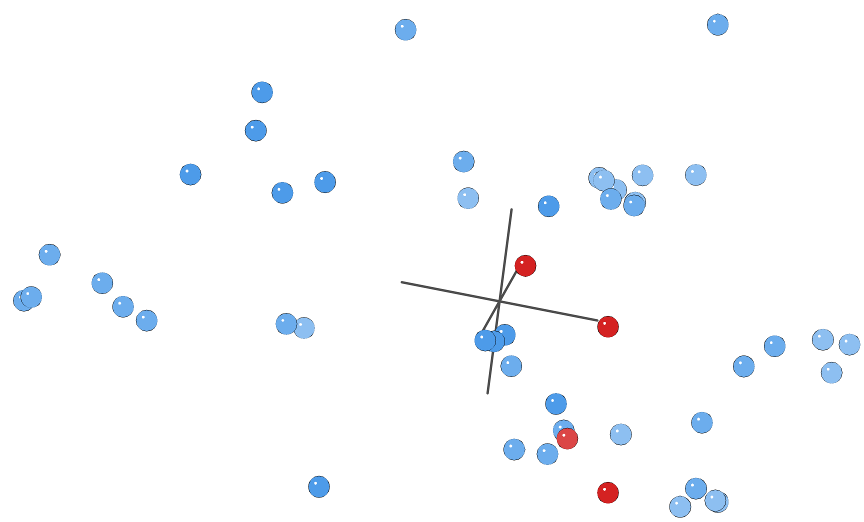
Order Rodentia
Family Octodontidae

Published taxa	54
Published characters	73
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	37
Characters used for calculations	44
Median bootstrap value	76
F_{90}	0.29
Stress of 3D MDS	0.15
k_{min}	4
Conclusion	Inc

Notes: In BDC, there appear to be two groups, but *Protadelphomys* shares positive BDC with members of both groups. There is no obvious clustering in the MDS results. There is no clear evidence of discontinuity.

Carvalho, G.A. and L.O. Salles. 2004. Relationships among extant and fossil echimyids (Rodentia: Hystricognathi). *Zoological Journal of the Linnean Society* 142:445-477.
Characters: Craniodental



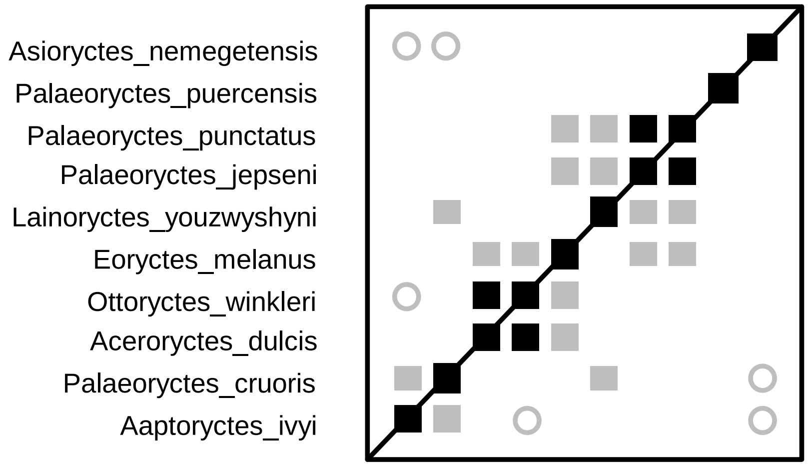


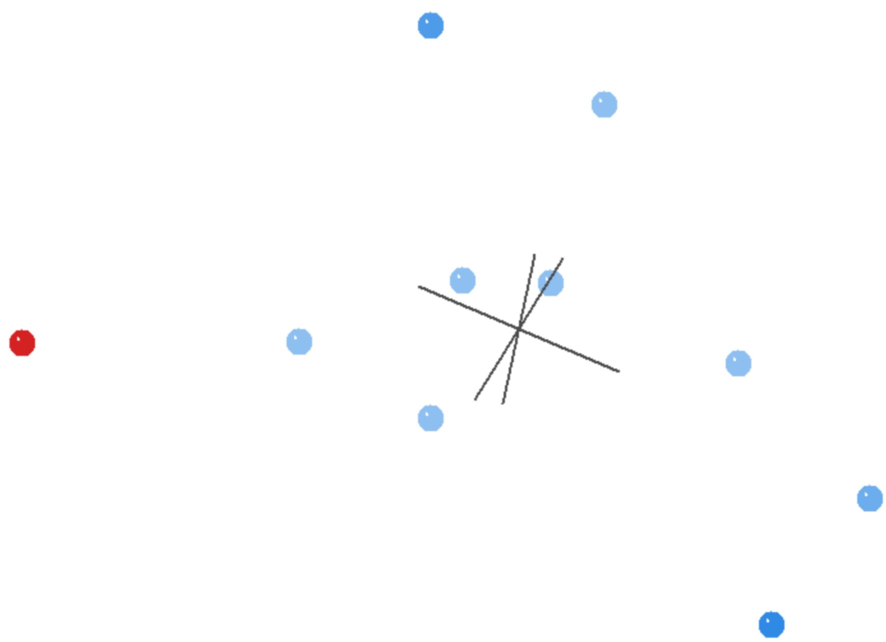
Order Rodentia
Family Echimyidae

Published taxa	54
Published characters	50
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	50
Characters used for calculations	37
Median bootstrap value	78
F_{90}	0.34
Stress of 3D MDS	0.13
k_{min}	3
Conclusion	Inc

Notes: Inconclusive; no strong evidence of discontinuity.

Rankin, B.D. and P.A. Holroyd. 2014. *Acerorycyes dulcis*, a new palaeoryctid (Mammalia, Eutheria) from the early Eocene of the Wasatch Formation of southwestern Wyoming, USA. *Canadian Journal of Earth Sciences* 51:919-926.
Characters: Dental



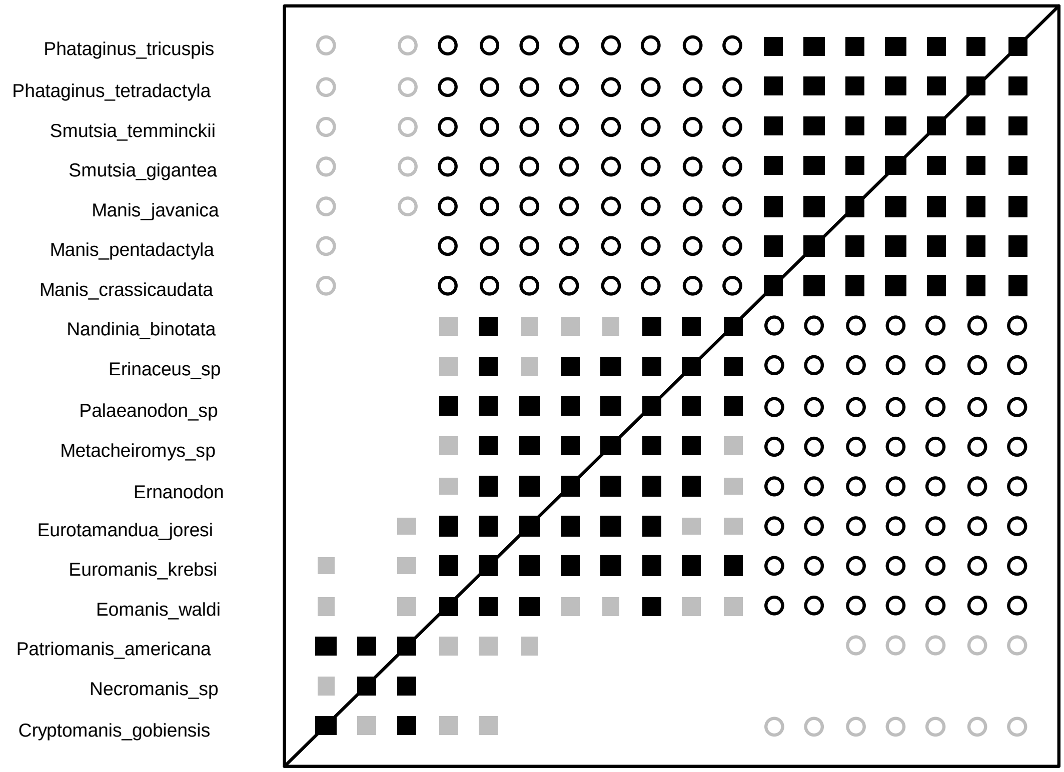


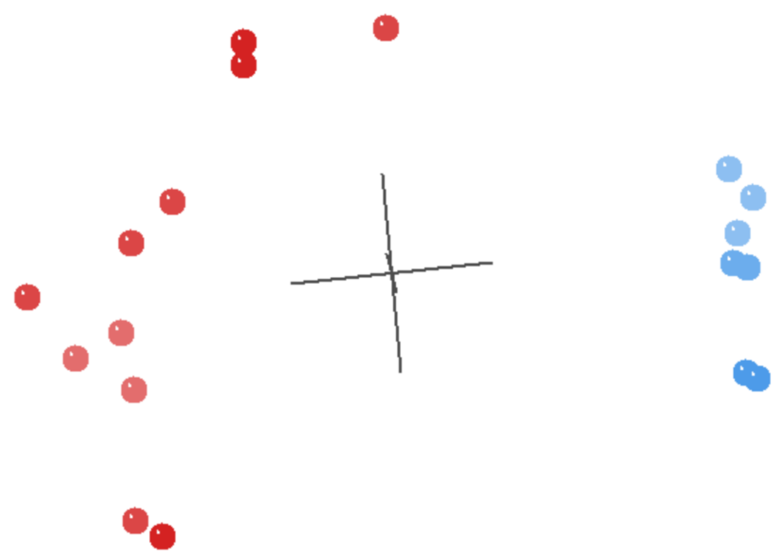
Order Insectivora
Family Palaeoryctidae

Published taxa	10
Published characters	32
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	10
Characters used for calculations	18
Median bootstrap value	78
F_{90}	0.09
Stress of 3D MDS	0.17
k_{min}	4
Conclusion	Inc

Notes: The outgroup taxon *Asioryctes* is moderately separated from the ingroup taxa, but not sufficiently to warrant inferring discontinuity.

Kondrashov, P. and A.K. Agadjanian. 2012. A nearly complete skeleton of *Ernanodon* (Mammalia, Palaeanodonta) from Mongolia: morphofunctional analysis. *Journal of Vertebrate Paleontology* 32:983-1001.
Characters: Cranial and postcranial



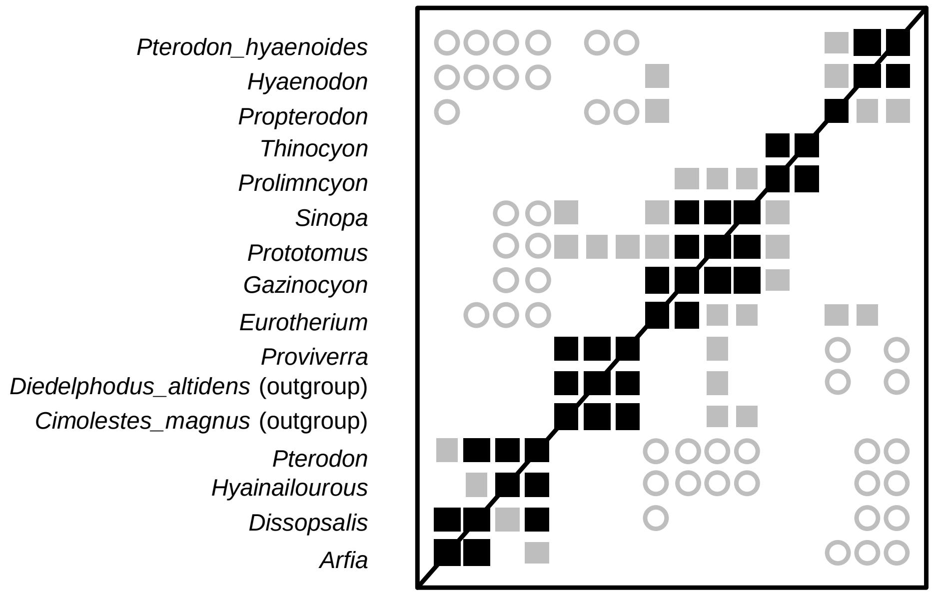


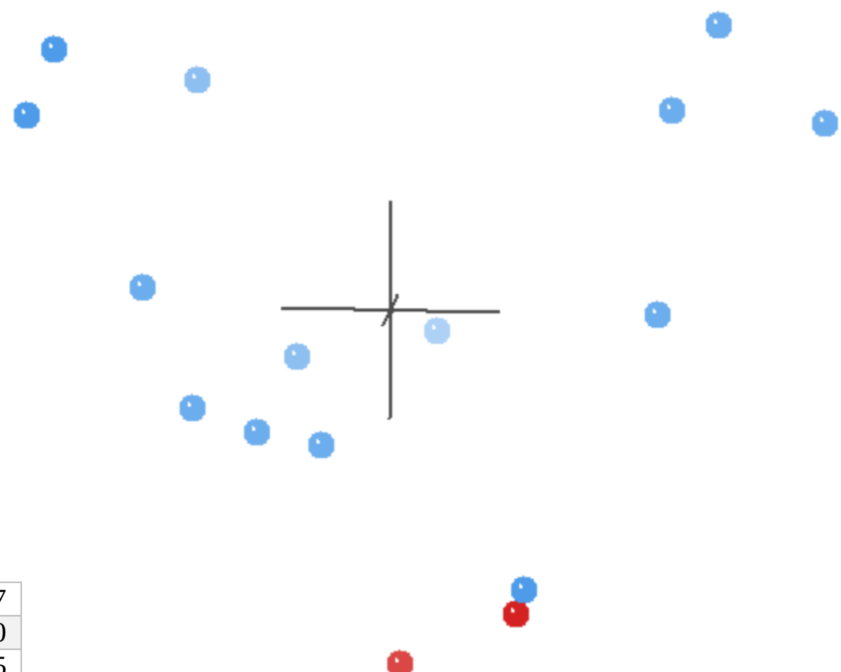
Order Pholidota
Family Manidae

Published taxa	18
Published characters	395
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	18
Characters used for calculations	209
Median bootstrap value	100
F_{90}	0.77
Stress of 3D MDS	0.16
k_{min}	9
Conclusion	HB

Notes: Manidae is well-separated in both BDC and MDS results. Manidae is probably a holobaramin.

Polly, P.D. 1996. The skeleton of *Gazinocyon vulpeculus* gen. et comb. nov. and the cladistic relationships of Hyaenodontidae (Eutheria, Mammalia). *Journal of Vertebrate Paleontology* 16:303-319.
Characters: Craniodental and postcranial



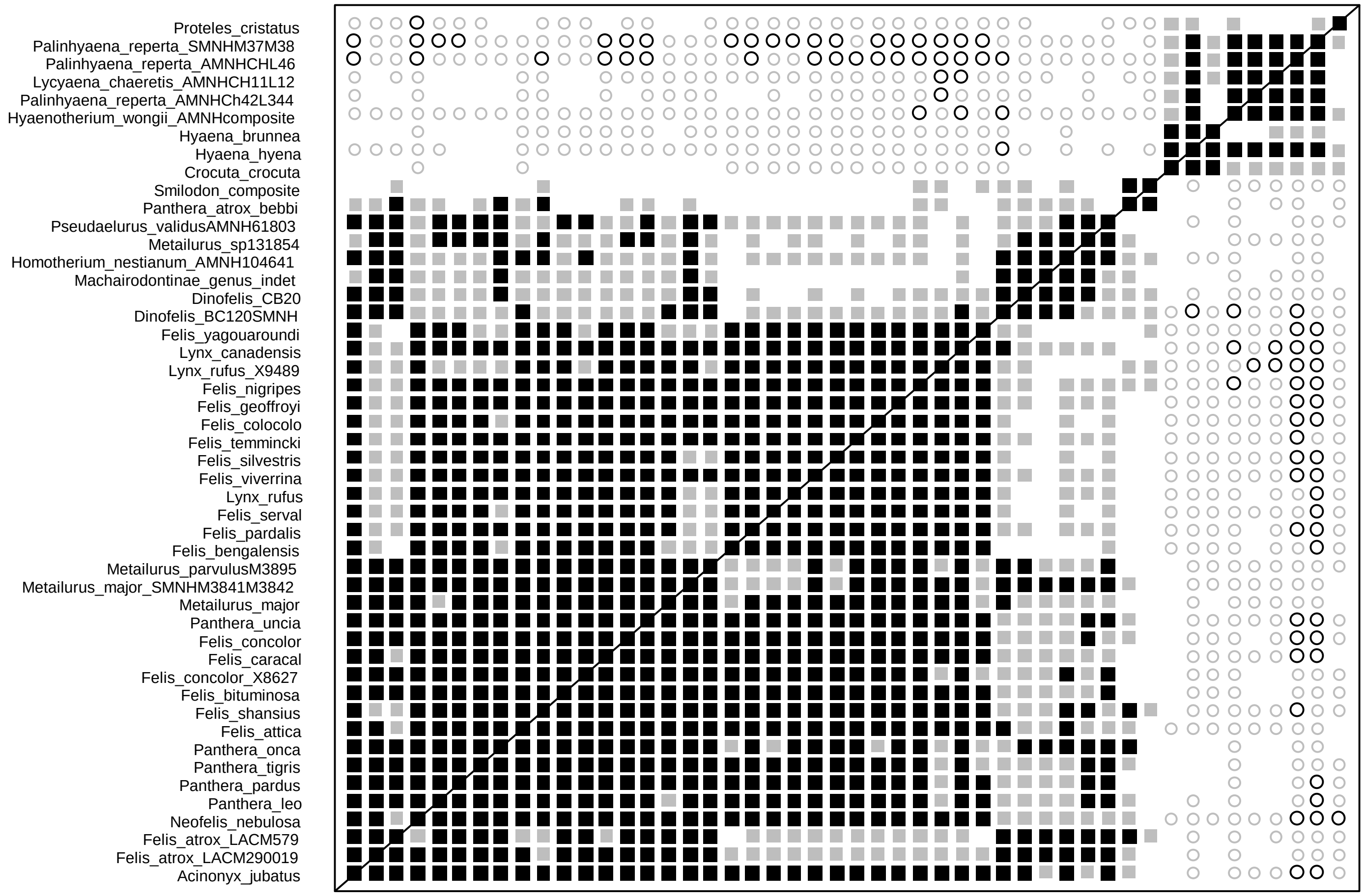


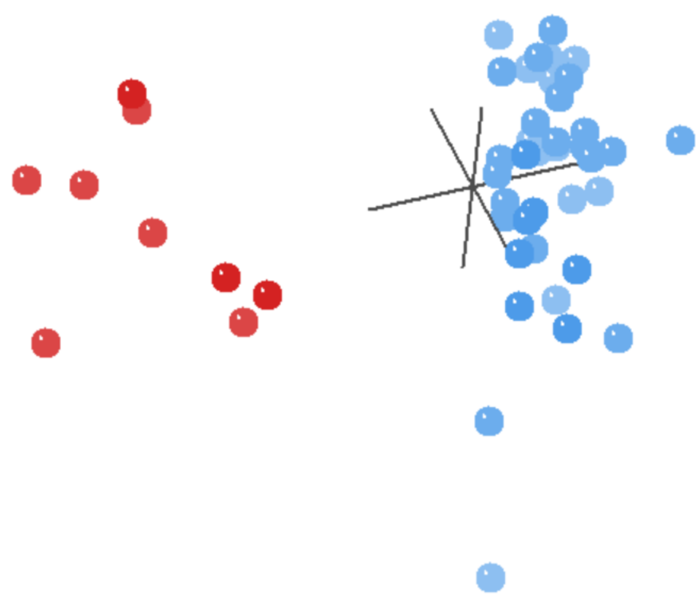
Order Carnivora
Family Hyaenodontidae

Published taxa	17
Published characters	60
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	16
Characters used for calculations	32
Median bootstrap value	75
F_{90}	0.12
Stress of 3D MDS	0.12
k_{min}	5
Conclusion	Inc

Notes: The BDC results mostly have poor bootstrap values, and there is no discontinuity evident in the MDS.

Holliday, J.A. 2007. Phylogeny and character change in the feloid Carnivora. Ph.D. Dissertation. Tallahassee, FL: Florida State University.
Characters: Craniodental



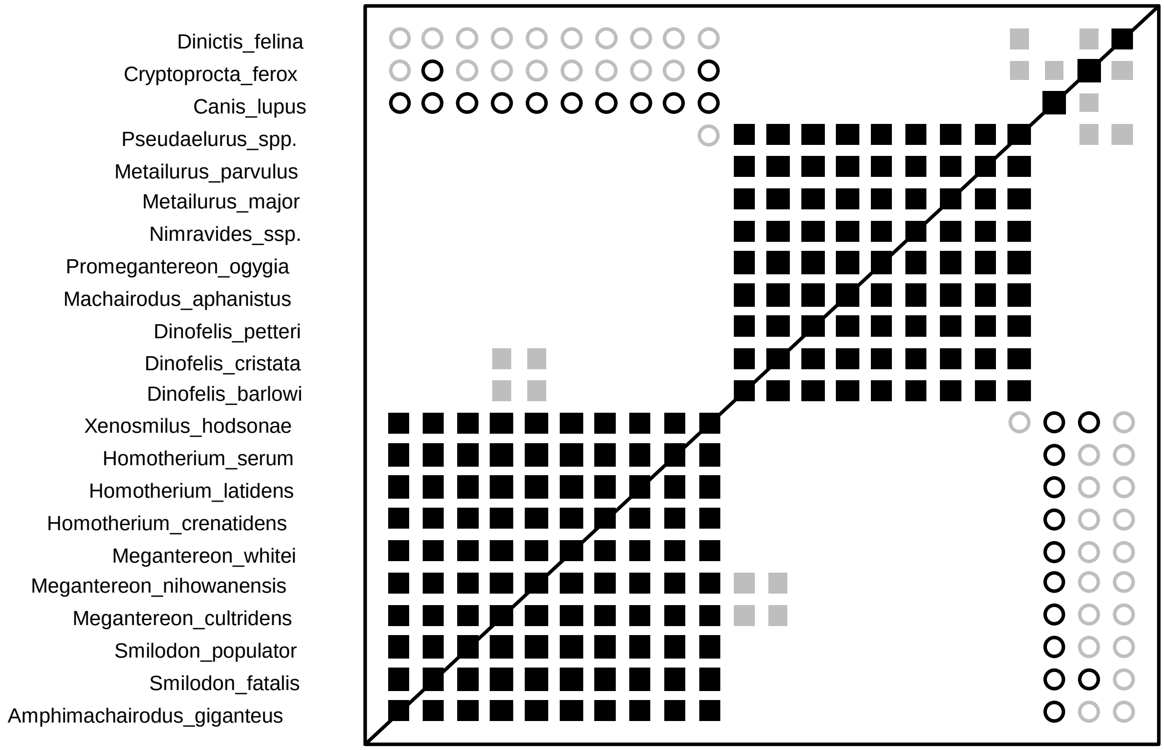


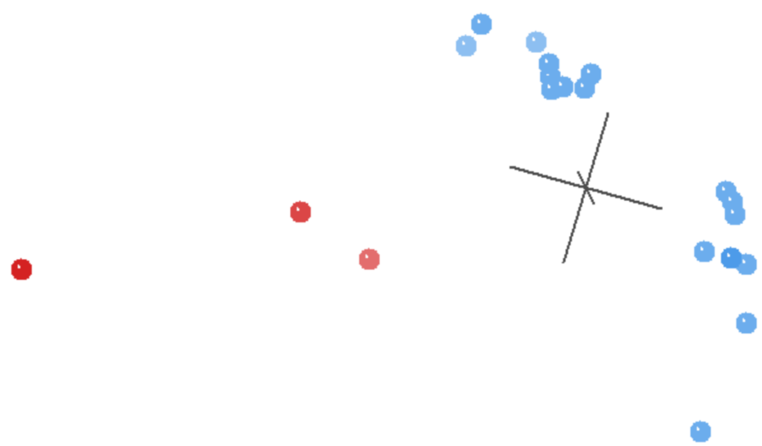
Order Carnivora
Family Felidae

Published taxa	168
Published characters	154
Character relevance	0.75
Taxic relevance	0.5
Taxa used for calculations	48
Characters used for calculations	103
Median bootstrap value	87
F_{90}	0.46
Stress of 3D MDS	0.32
k_{min}	11
Conclusion	HB

Notes: The published dataset was trimmed to include just the Felidae and Hyaenidae as in Robinson and Cavanaugh's original analysis (1998. Evidence for a holobaraminic origin of the cats. *CRSQ* 35:2-14). BDC and MDS support a discontinuity between the two families. Felidae is likely a holobaramin.

Christiansen, P. 2013. Phylogeny of the sabertoothed felids (Carnivora: Felidae: Machairodontinae). *Cladistics* 29:543-559.
Characters: Craniodental



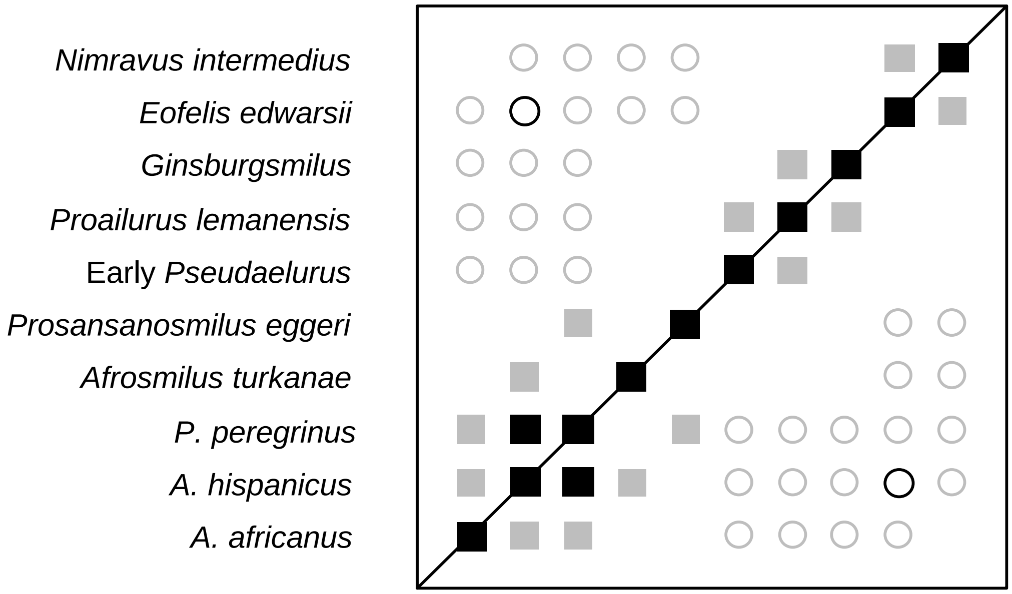


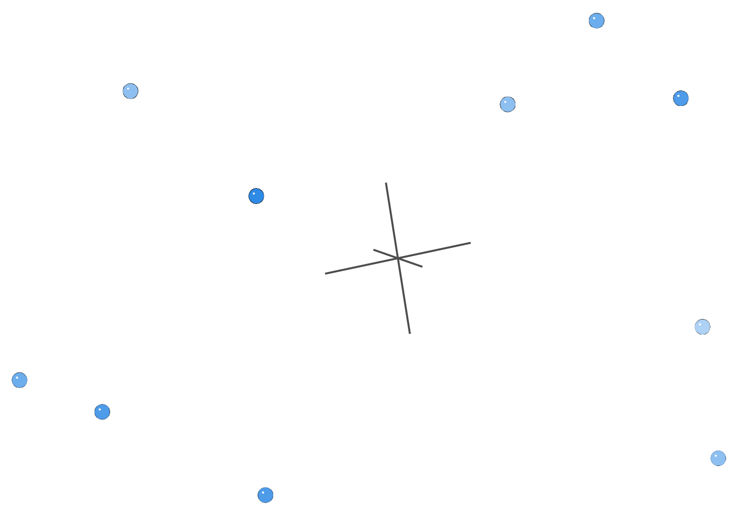
Order Carnivora
Family Felidae

Published taxa	22
Published characters	50
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	22
Characters used for calculations	50
Median bootstrap value	85
F_{90}	0.41
Stress of 3D MDS	0.12
k_{min}	6
Conclusion	HB

Notes: Machairodontinae is the focus of this character set, but there are four extinct genera recognized as Felinae by McKenna and Bell (1997): *Pseudalurus*, *Metailurus*, *Nimravides*, and *Dinofelis*. Results show the felids well-separated from outgroup taxa in MDS and BDC results. BDC indicates two groups of felids with positive BDC between them (but with poor bootstrap values between them). Felidae is likely a holobaramin.

Morlo, M., S. Peigne, and D. Nagel. 2004. A new species of *Prosansanosmilus*: implications for the systematic relationships of the family Barbourofelidae new rank (Carnivora, Mammalia). *Zoological Journal of the Linnean Society* 140:43-61.
Characters: Dental



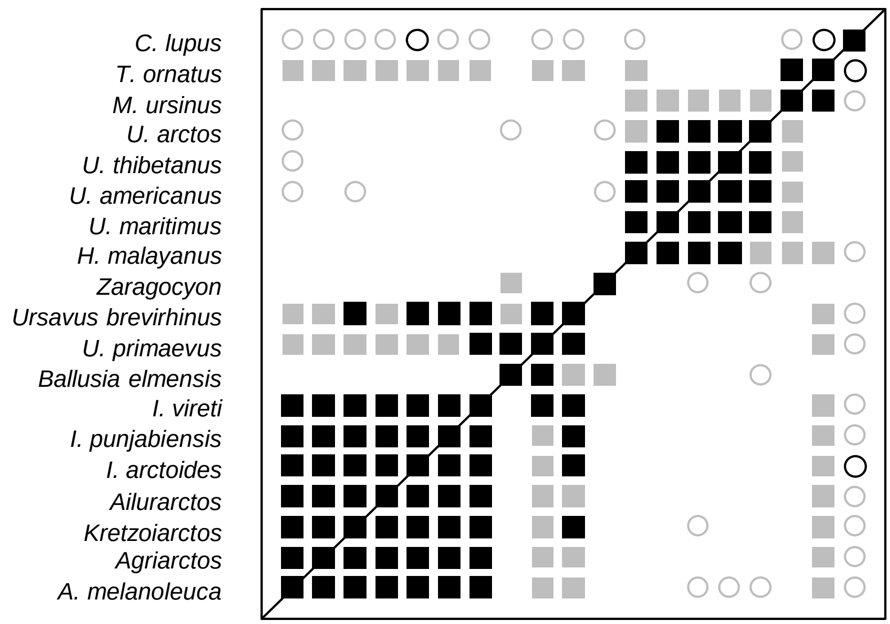


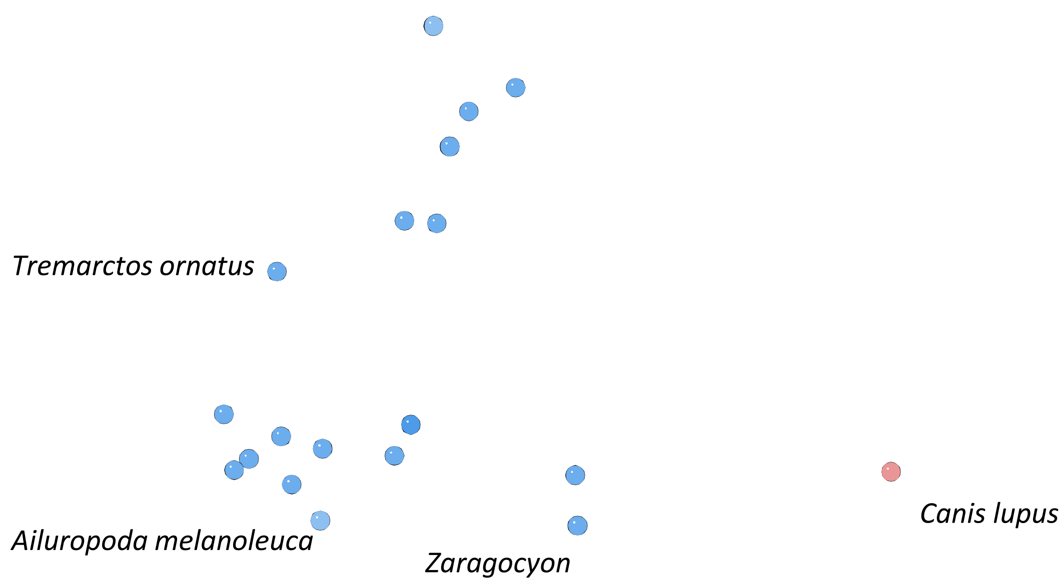
Order Carnivora
Subfamily Barbourofelinae

Published taxa	11
Published characters	22
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	10
Characters used for calculations	16
Median bootstrap value	71
F_{90}	0.11
Stress of 3D MDS	0.1
k_{min}	3
Conclusion	Inc

Notes: The BDC results have poor bootstrap values, and the MDS reveals a diffuse distribution of taxa. There is no evidence of discontinuity.

Abella, J., D.M. Alba, J.M. Robles, A. Valenciano, C. Rotgers, R. Carmona, P. Montoya, and J. Morales. 2012. *Kretzoiarctos* gen. nov., the oldest member of the giant panda clade. *PLoS ONE* 7:e48985.
Characters: Craniodental



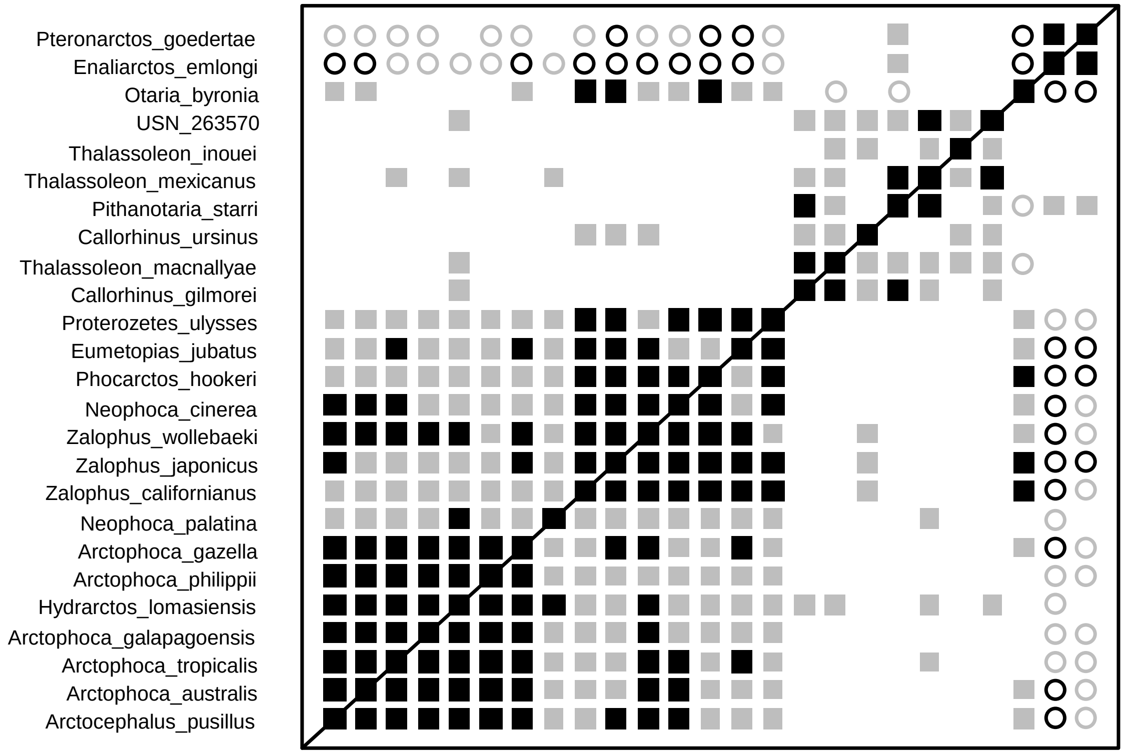


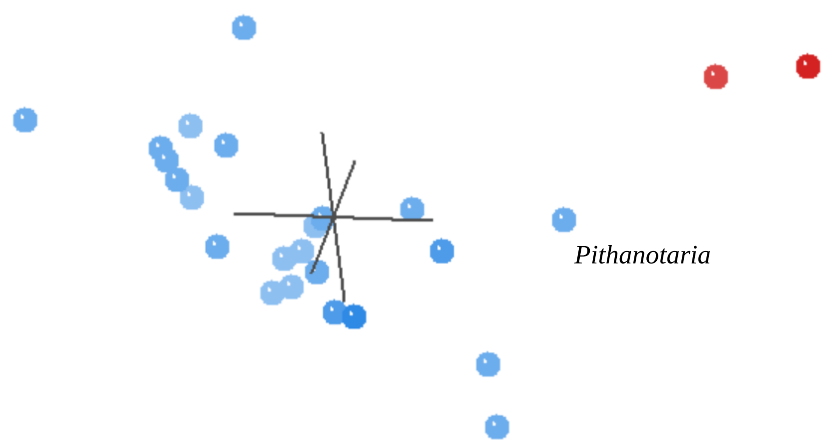
Order Carnivora
Family Ursidae

Published taxa	19
Published characters	82
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	19
Characters used for calculations	53
Median bootstrap value	82
F_{90}	0.23
Stress of 3D MDS	0.14
k_{min}	5
Conclusion	HB?

Notes: Ursidae is well-separated from the outgroup taxon *Canis lupus* in both BDC and MDS results. Within the group, ursids form two groups that are connected only by the spectacled bear *Tremarctos ornatus*, which also appears in an intermediate position in the MDS results. Ursidae appears to be a holobaramin.

Churchill, M., R.W. Boessenecker, and M.T. Clementz. 2014. Colonization of the southern hemisphere by fur seals and sea lions (Carnivora: Otariidae) revealed by combined evidence phylogenetic and Bayesian biogeographical analysis. *Zoological Journal of the Linnean Society* 172:200-225.
Characters: Craniodental, postcranial, behavioral



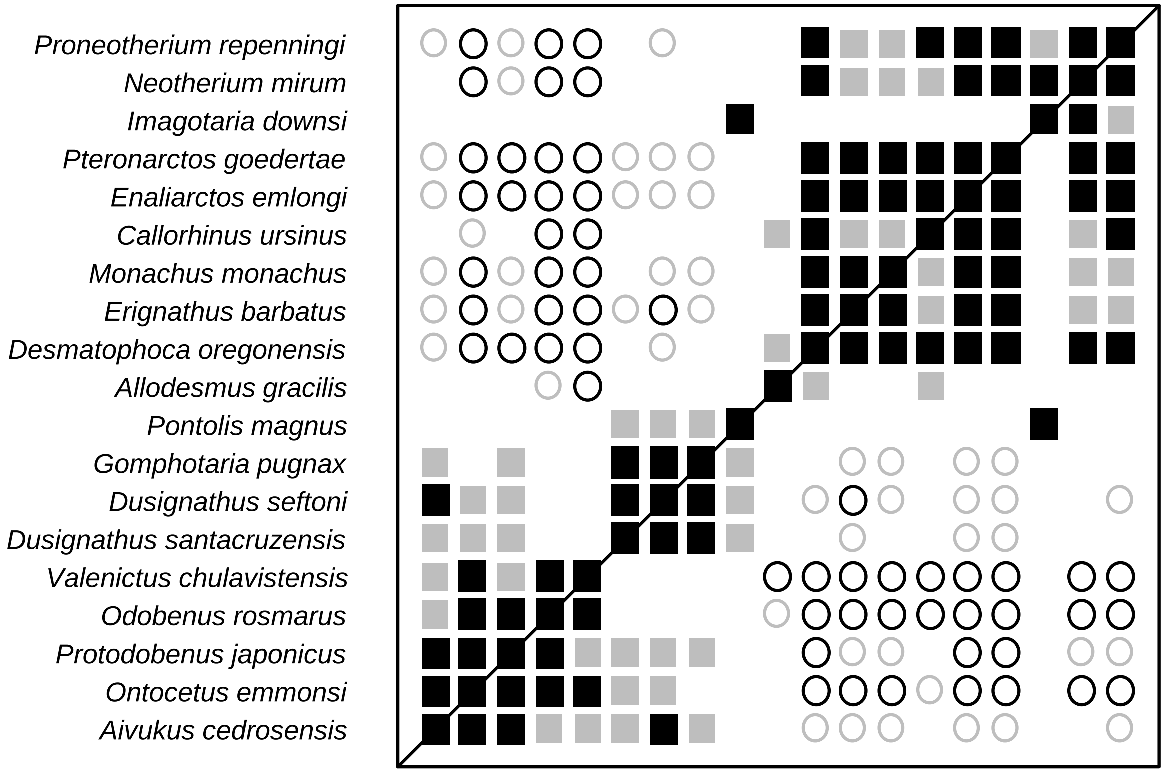


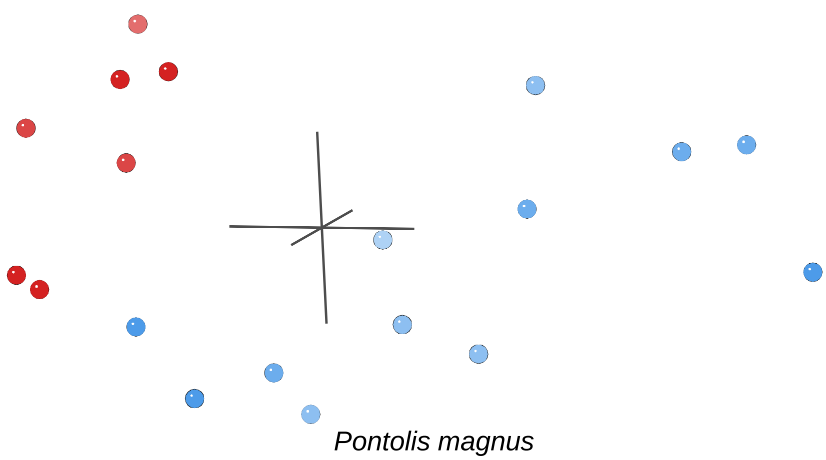
Order Carnivora
Family Otariidae

Published taxa	25
Published characters	107
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	25
Characters used for calculations	84
Median bootstrap value	80
F_{90}	0.24
Stress of 3D MDS	0.26
k_{min}	10
Conclusion	HB

Notes: Otariidae is well-separated from the outgroup taxa in both BDC and MDS results. BDC reveals positive correlation between the outgroup taxa and *Pithanotaria*, but their proximity is not evident in the MDS results. Otariidae is likely a holobaramin.

Boessenecker, R.W. and M. Churchill. 2013. A reevaluation of the morphology, paleoecology, and phylogenetic relationships of the enigmatic walrus *Pelagiarctos*. *PLoS One* 8:e54311.
Characters: Craniodental and postcranial



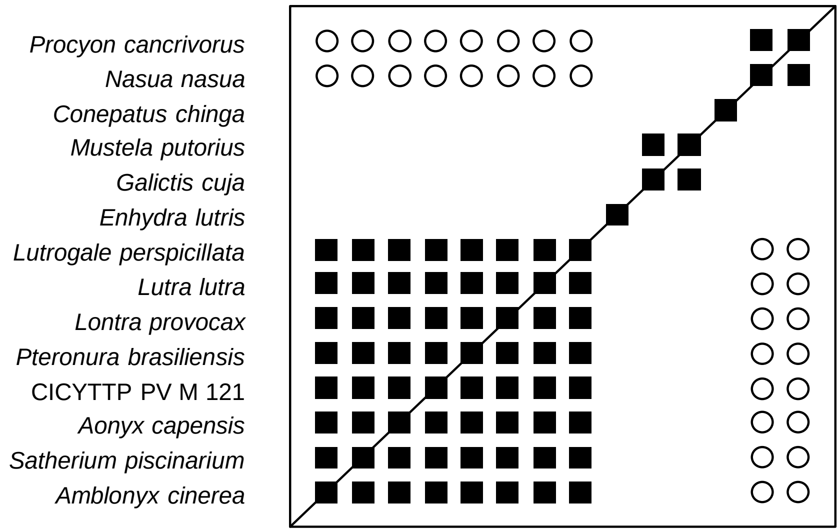


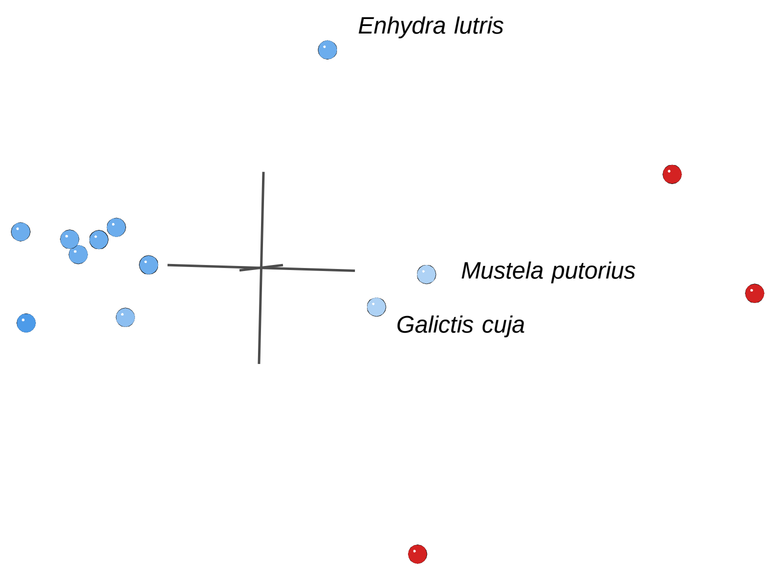
Order Carnivora
Family Odobenidae

Published taxa	23
Published characters	90
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	19
Characters used for calculations	82
Median bootstrap value	89
F_{90}	0.48
Stress of 3D MDS	0.14
k_{min}	7
Conclusion	HB?

Notes: Odobenidae is well separated from the outgroup taxa in the BDC results, with the exception of *Pontolis*, which is positively correlated with members of the ingroup and outgroup. The MDS results do not reveal a clear distinction between the two groups, although *Pontolis* does not appear to be closely associated with the outgroup taxa. Odobenidae might be a holobaramin.

Prevosti, F.J. and B.S. Ferrero. 2008. A Pleistocene giant river otter from Argentina: remarks on the fossil record and phylogenetic analysis. *Journal of Vertebrate Paleontology* 28:1171-1181.
Characters: Craniodental



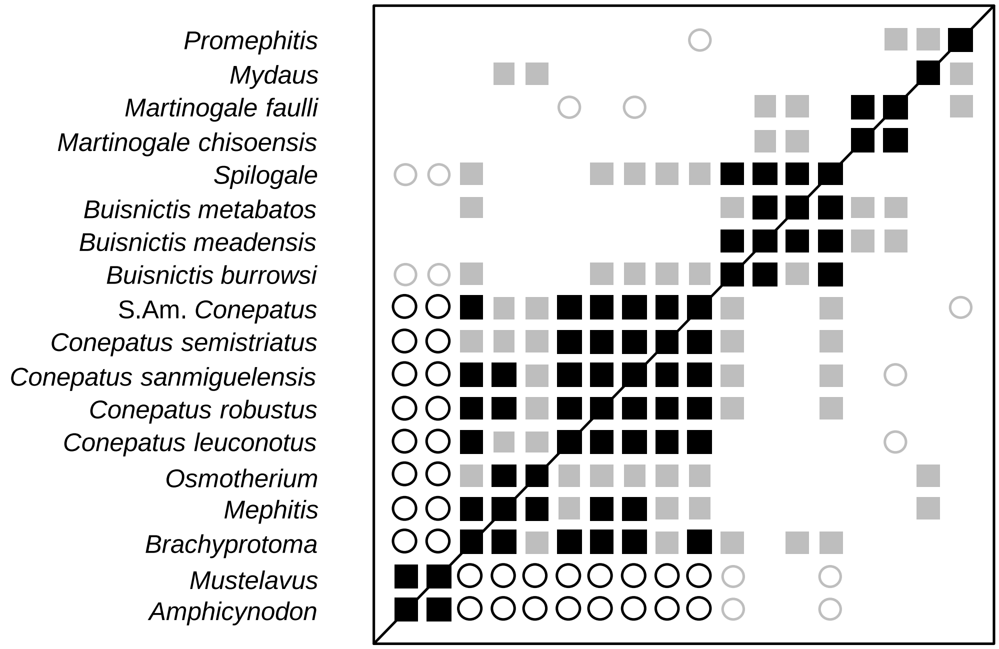


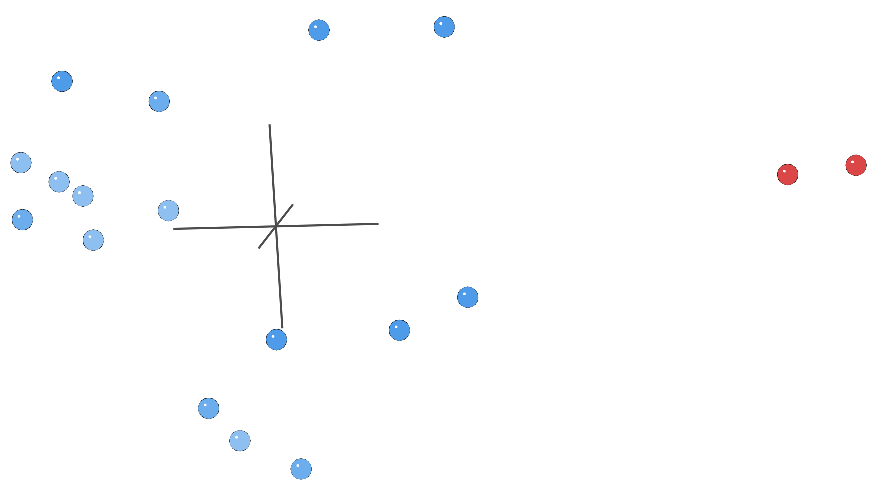
Order Carnivora
Family Mustelidae

Published taxa	41
Published characters	69
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	14
Characters used for calculations	64
Median bootstrap value	99
F_{90}	0.78
Stress of 3D MDS	0.11
k_{min}	6
Conclusion	HB?

Notes: A cluster of mustelid taxa appear to be a holobaramin, but *Mustela*, *Galictis* and *Enhydra* are not connected to the main cluster of mustelid taxa in either the MDS or BDC results. This result should be examined further.

Wang, X., Ó. Carranza-Castañeda, and J.J. Aranda-Gómez. 2014. A transitional skunk, *Buisnictis metabatos* sp. nov. (Mephitidae, Carnivora), from Baja California Sur and the role of southern refugia in skunk evolution. *Journal of Systematic Palaeontology* 12:291-302.
Characters: Craniodental



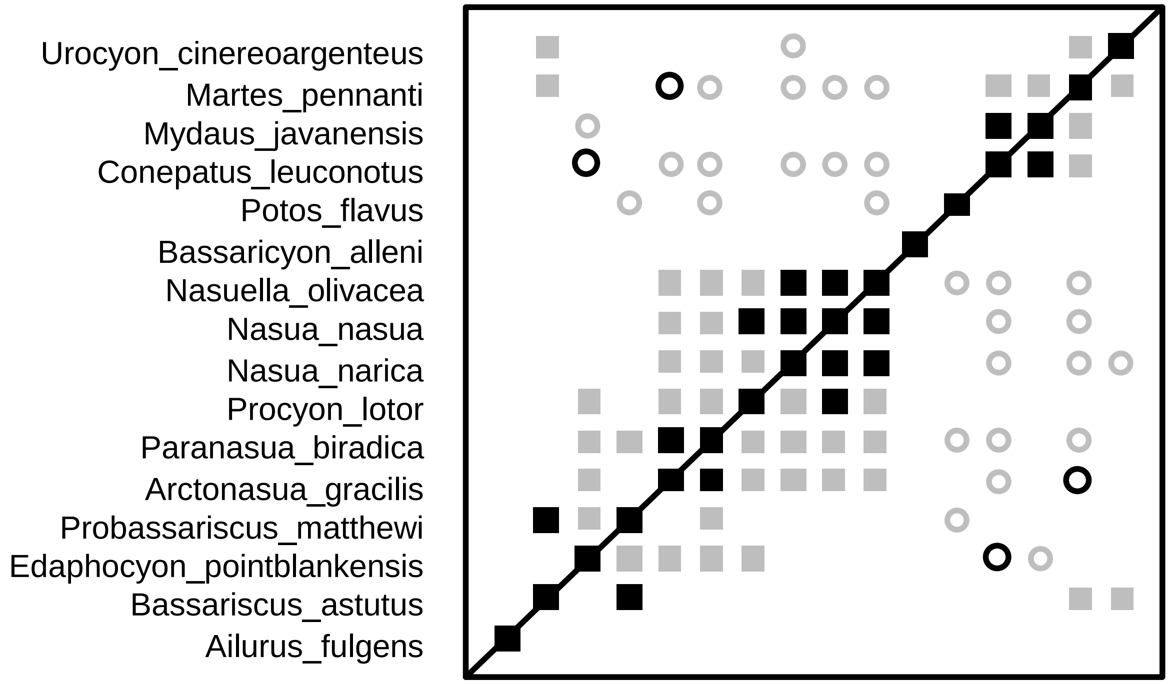


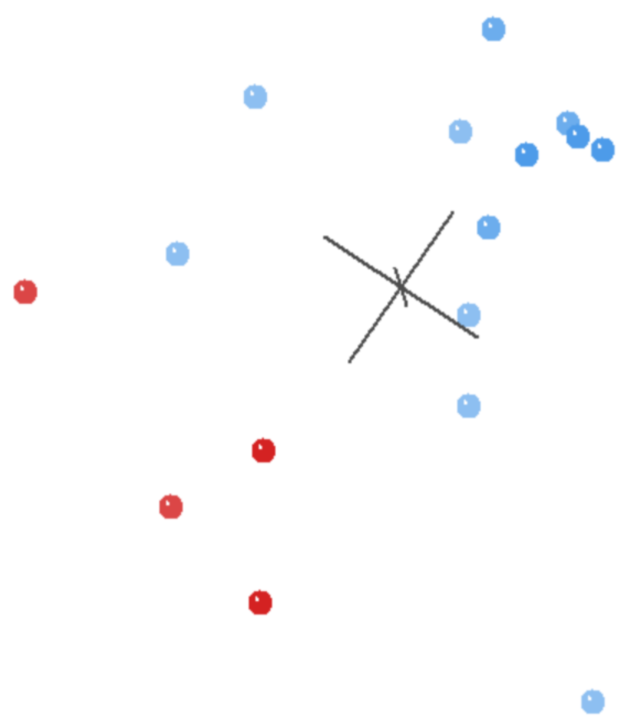
Order Carnivora
Family Mephitidae

Published taxa	21
Published characters	39
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	18
Characters used for calculations	31
Median bootstrap value	74
F_{90}	0.26
Stress of 3D MDS	0.09
k_{min}	4
Conclusion	HB

Notes: Mephitidae is clearly separated from the outgroup taxa in both BDC and MDS results. Mephitidae is likely a holobaramin.

Ahrens, H.E. 2012. Craniodental characters and the relationships of Procyonidae (Mammalia: Carnivora). *Zoological Journal of the Linnean Society* 164:669-713.
Characters: Craniodental



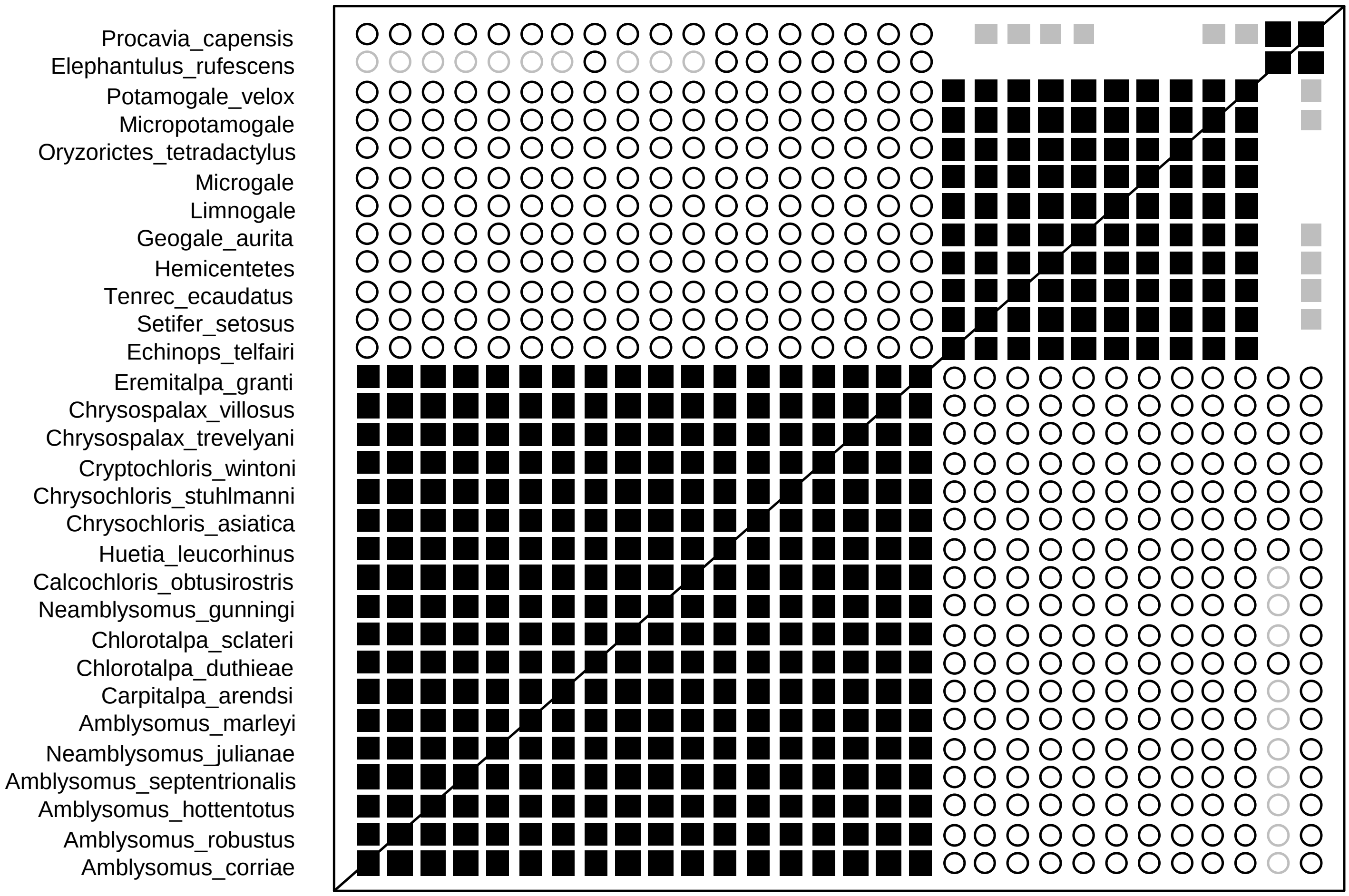


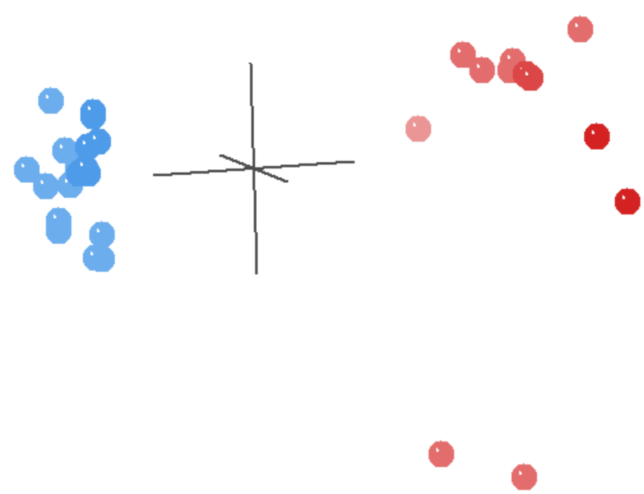
Order Carnivora
Family Procyonidae

Published taxa	20
Published characters	78
Character relevance	0.75
Taxic relevance	0.25
Taxa used for calculations	16
Characters used for calculations	69
Median bootstrap value	79
F_{90}	0.32
Stress of 3D MDS	0.15
k_{min}	6
Conclusion	Inc

Notes: BDC results shows potential discontinuity around some procyonid taxa, but the MDS results show a diffuse cloud of all taxa. There is no clear evidence of discontinuity.

Asher, R.J., S. Maree, G. Bronner, N.C. Bennett, P. Bloomer, P. Czechowski, M. Meyer, and M. Hofreiter. 2010. A phylogenetic estimate for golden moles (Mammalia, Afrotheria, Chrysochloridae). *BMC Evolutionary Biology* 10:69.
Characters: Craniodental and postcranial



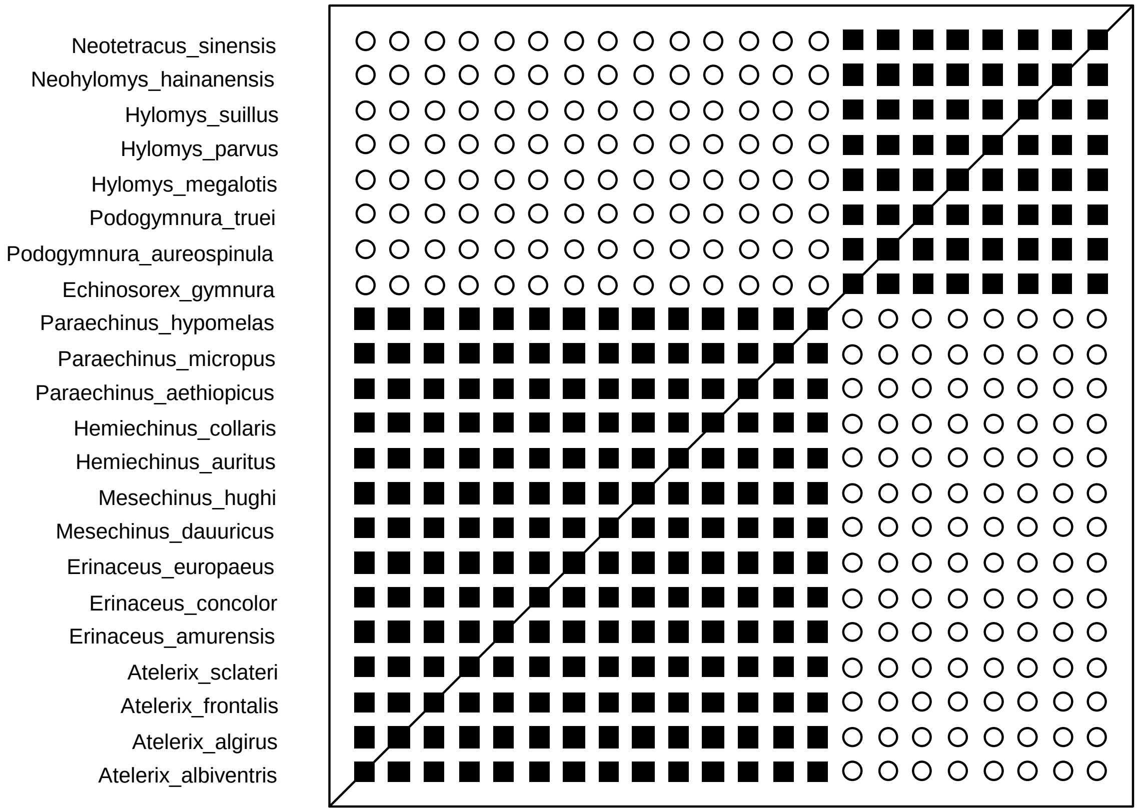


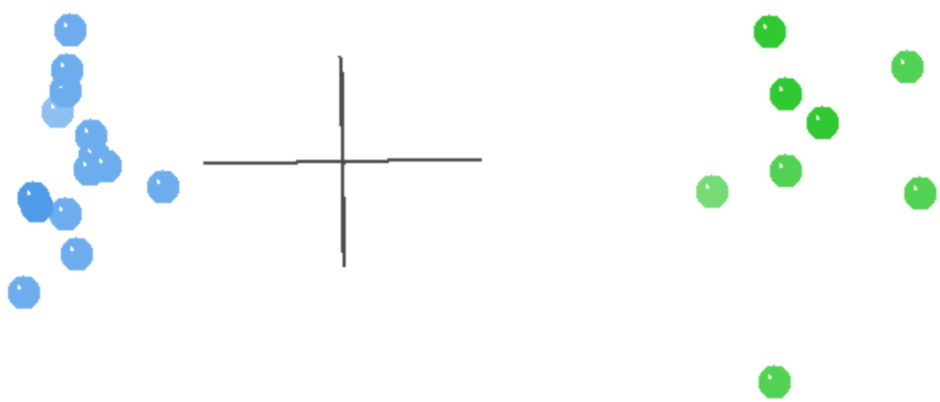
Order Chrysochloridea
Family Chrysochloridae

Published taxa	30
Published characters	144
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	30
Characters used for calculations	134
Median bootstrap value	100
F_{90}	0.93
Stress of 3D MDS	0.11
k_{min}	6
Conclusion	HB

Notes: Chrysochloridae is well-separated from the outgroup taxa in MDS and BDC results. Chrysochloridae is a holobaramin.

He, K., J.-H. Chen, G.C. Gould, N. Yamaguchi, H.-S. Ai, Y.-X. Wang, Y.-P. Zhang, and X.-L. Jiang. 2012. An estimation of Erinaceidae phylogeny: a combined analysis approach. *PLoS ONE* 7(6):e39304.
Characters: Craniodental, postcranial, external morphology



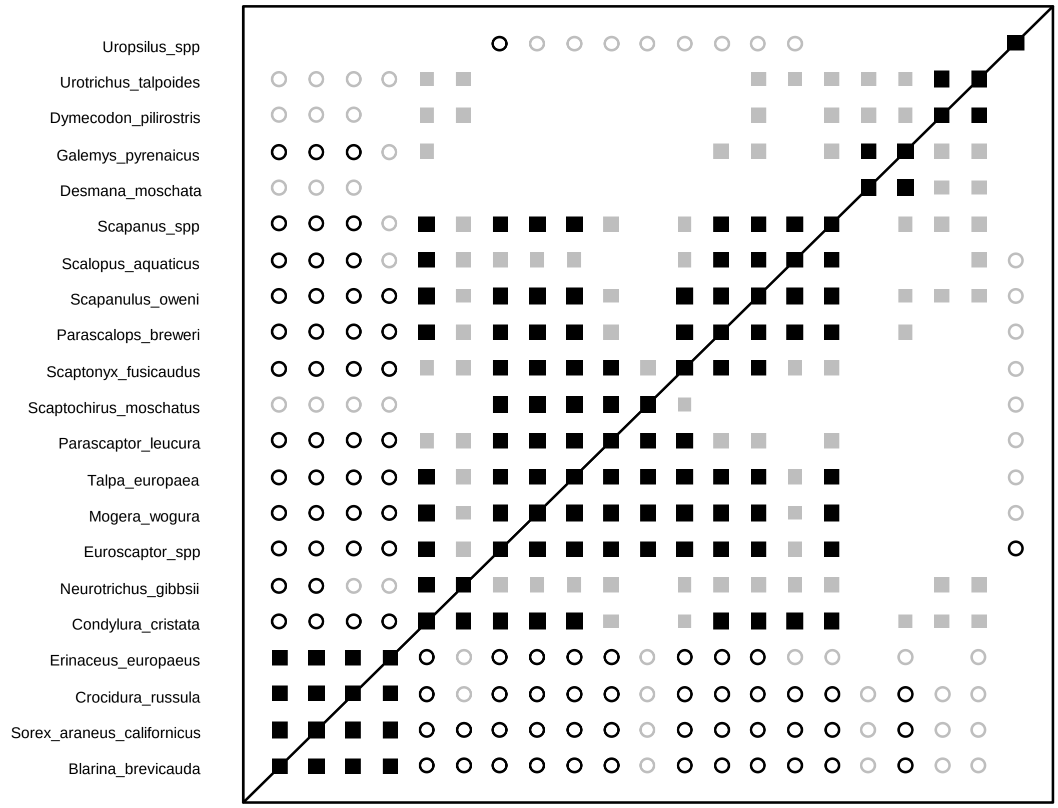


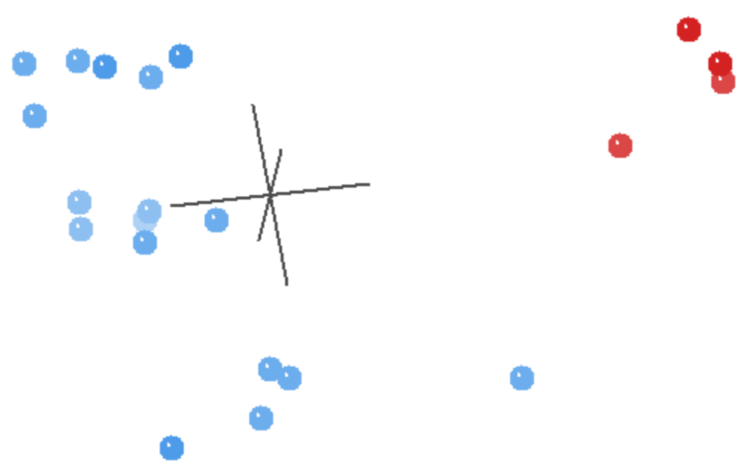
Order Erinaceomorpha
Family Erinaceidae

Published taxa	23
Published characters	135
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	23
Characters used for calculations	97
Median bootstrap value	100
F_{90}	1
Stress of 3D MDS	0.07
k_{min}	4
Conclusion	HB

Notes: Subfamilies Erinaceinae and Galericinae are both well-separated in the BDC and MDS results. Both are likely holobaramins.

Sánchez-Villagra, M.R., I. Horovitz, and M. Motokawa. 2006. A comprehensive morphological analysis of talpid moles (Mammalia) phylogenetic relationships. *Cladistics* 22:59-88.
Characters: Craniodental and postcranial



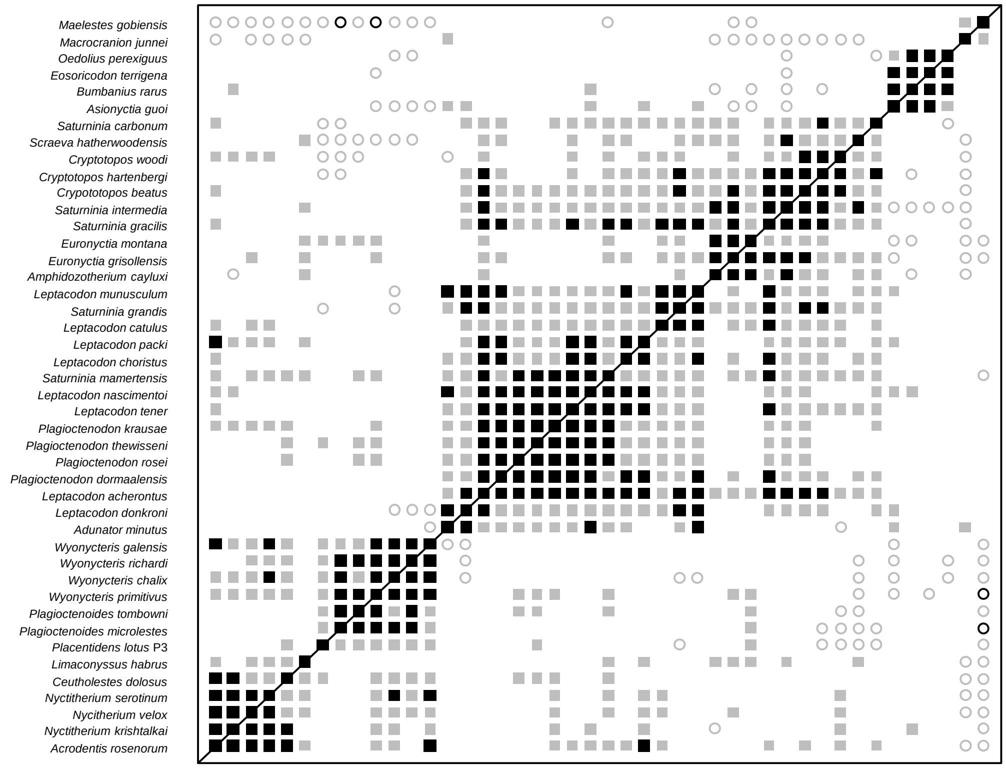


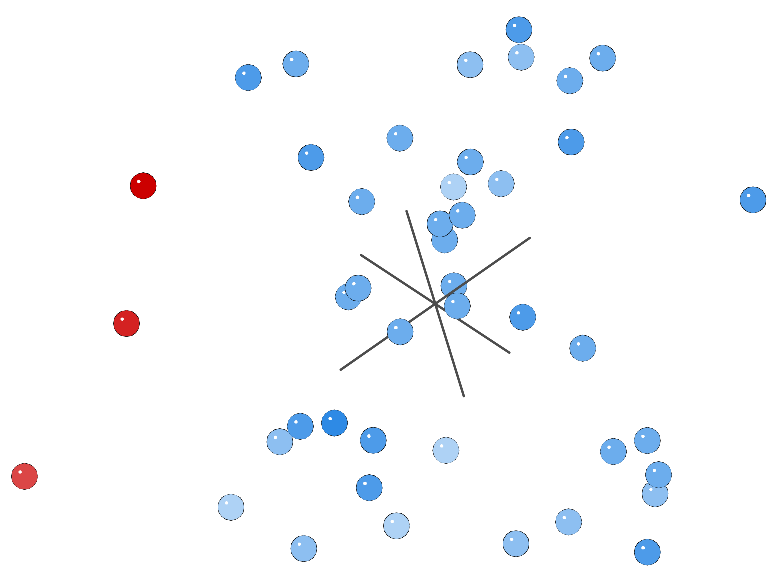
Order Erinaceomorpha
Family Talpidae

Published taxa	21
Published characters	157
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	21
Characters used for calculations	135
Median bootstrap value	90
F_{90}	0.49
Stress of 3D MDS	0.21
k_{min}	9
Conclusion	HB

Notes: Talpidae is well-separated from the outgroup taxa in both the BDC and MDS results. Talpidae is likely a holobaramin.

Manz, C.L. and J.I. Bloch. 2015. Systematics and phylogeny of Paleocene-Eocene Nyctitheriidae (Mammalia, Eulipotyphla?) with description of a new species from the Late Paleocene of the Clarks Fork Basin, Wyoming, USA. *Journal of Mammalian Evolution* 22:307-342.
Characters: Dental



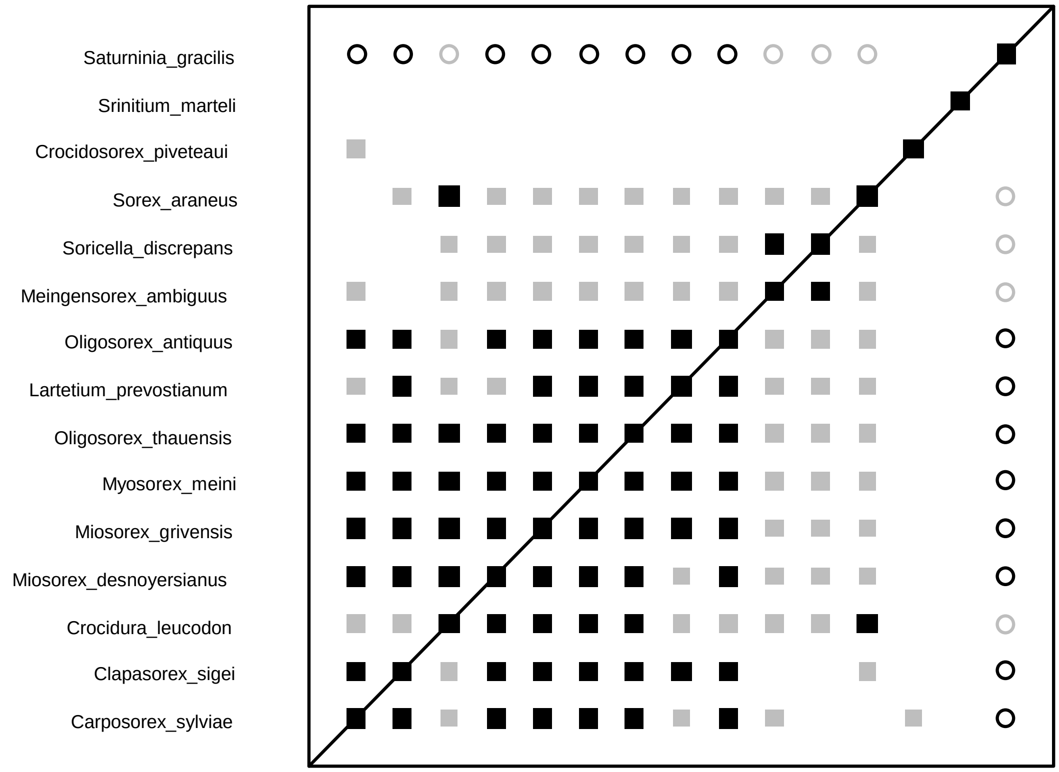


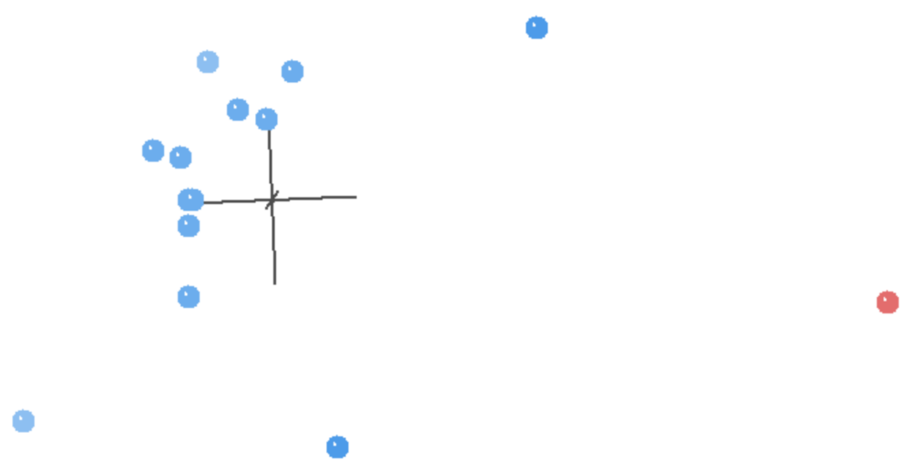
Order Soricomorpha
Family Nyctitheriidae

Published taxa	54
Published characters	66
Character relevance	0.75
Taxic relevance	0.5
Taxa used for calculations	44
Characters used for calculations	34
Median bootstrap value	65
F_{90}	0.1
Stress of 3D MDS	0.3
k_{min}	7
Conclusion	HB?

Notes: BDC seems to support separation between the outgroup taxa and ingroup taxa, but the MDS results are far less clear. Given that the 3D stress is high (0.3), we may very tentatively accept Nyctitheriidae as a holobaramin.

Hugueney, M. and O. Maridet. 2011. Early Miocene soricids (Insectivora, Mammalia) from Limagne (Central France): new systematic comparisons, updated biostratigraphic data and evolutionary implications. *Geobios* 44:225-236.
Characters: Craniodental



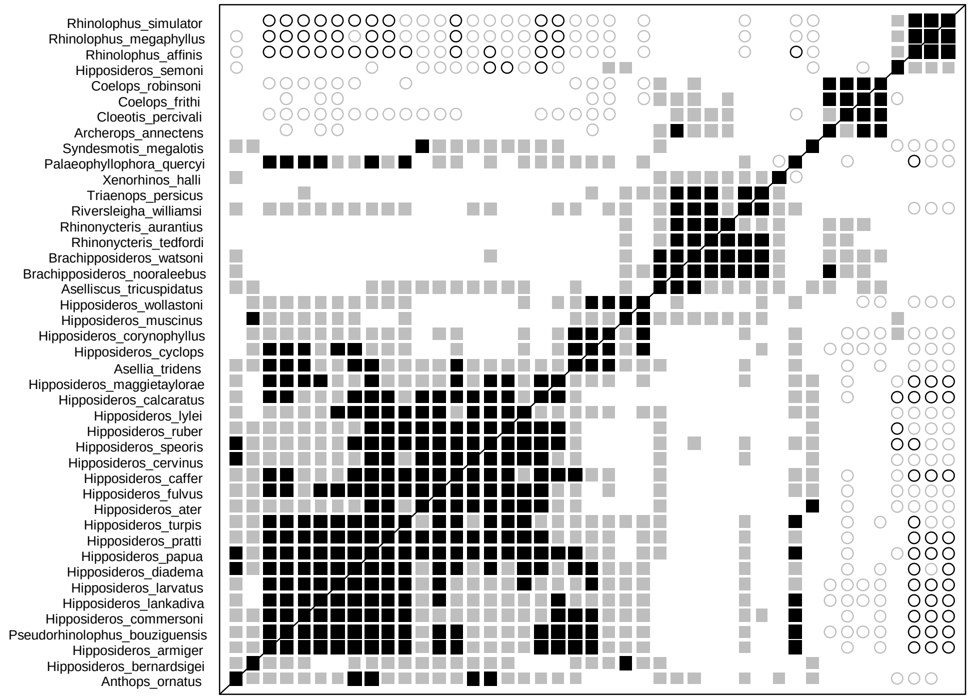


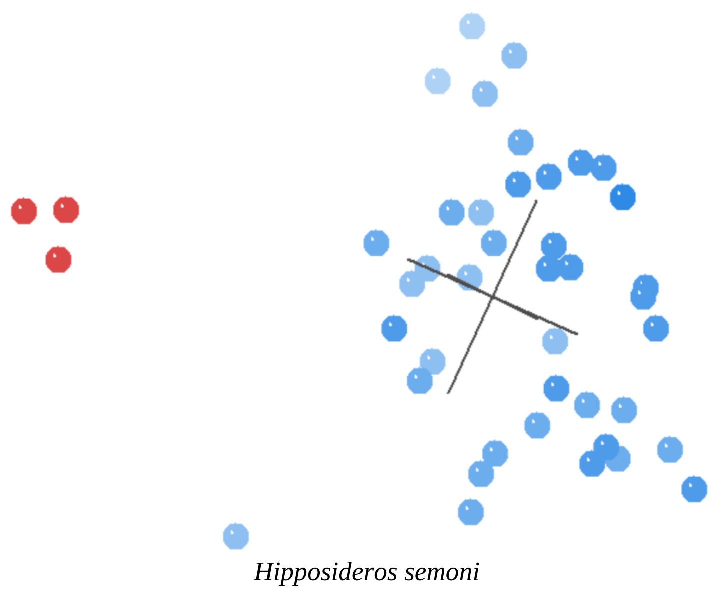
Order Soricomorpha
Family Soricidae

Published taxa	15
Published characters	27
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	15
Characters used for calculations	21
Median bootstrap value	79
F_{90}	0.34
Stress of 3D MDS	0.22
k_{min}	5
Conclusion	HB?

Notes: Soricidae is well separated from the outgroup in BDC and MDS results. Soricidae is likely a holobaramin based on these characters.

Hand, S.J. and J.A.W. Kirsch. 2003. *Archerops*, a new annectent hipposiderid genus (Mammalia: Microchiroptera) from the Australian Miocene. *Journal of Paleontology* 77:1139-1151.
Characters: Craniodental and postcranial



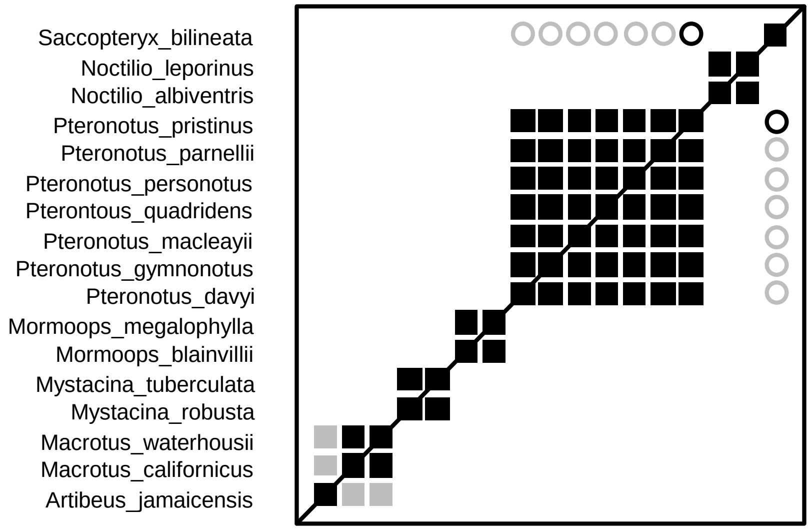


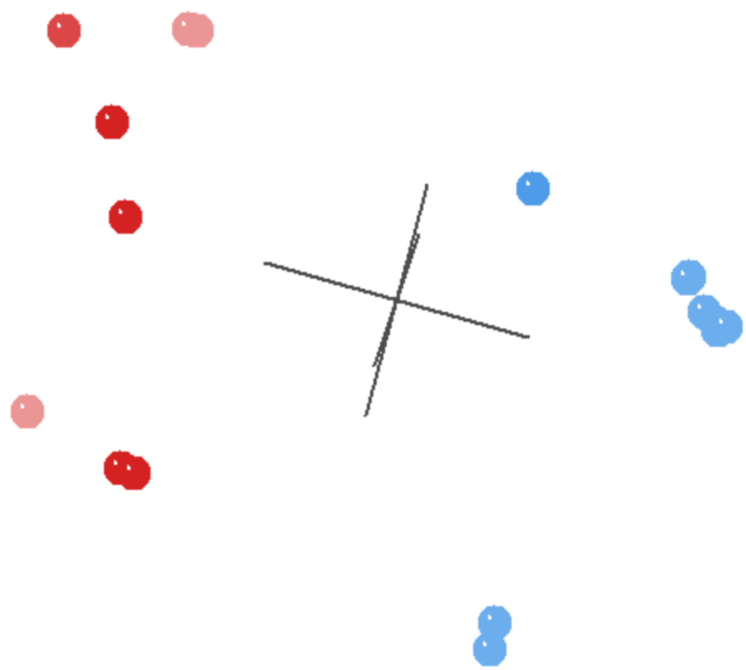
Order Chiroptera
Family Rhinolophidae

Published taxa	44
Published characters	64
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	44
Characters used for calculations	64
Median bootstrap value	73
F_{90}	0.2
Stress of 3D MDS	0.32
k_{min}	11
Conclusion	HB?

Notes: BDC and MDS support a separation between Rhinolophidae and outgroup taxa. *Hipposideros semoni* shares positive BDC with all outgroup taxa and two other rhinolophids, but the MDS supports including *H. semoni* in the rhinolophid cluster. Rhinolophidae is likely a holobaramin.

Simmons, N.B. and T.M. Conway. 2001. Phylogenetic relationships of mormoopid bats (Chiroptera: Mormoopidae) based on morphological data. *Bulletin of the American Museum of Natural History* 258:1-97.
Characters: Craniodental, postcranial, soft tissue



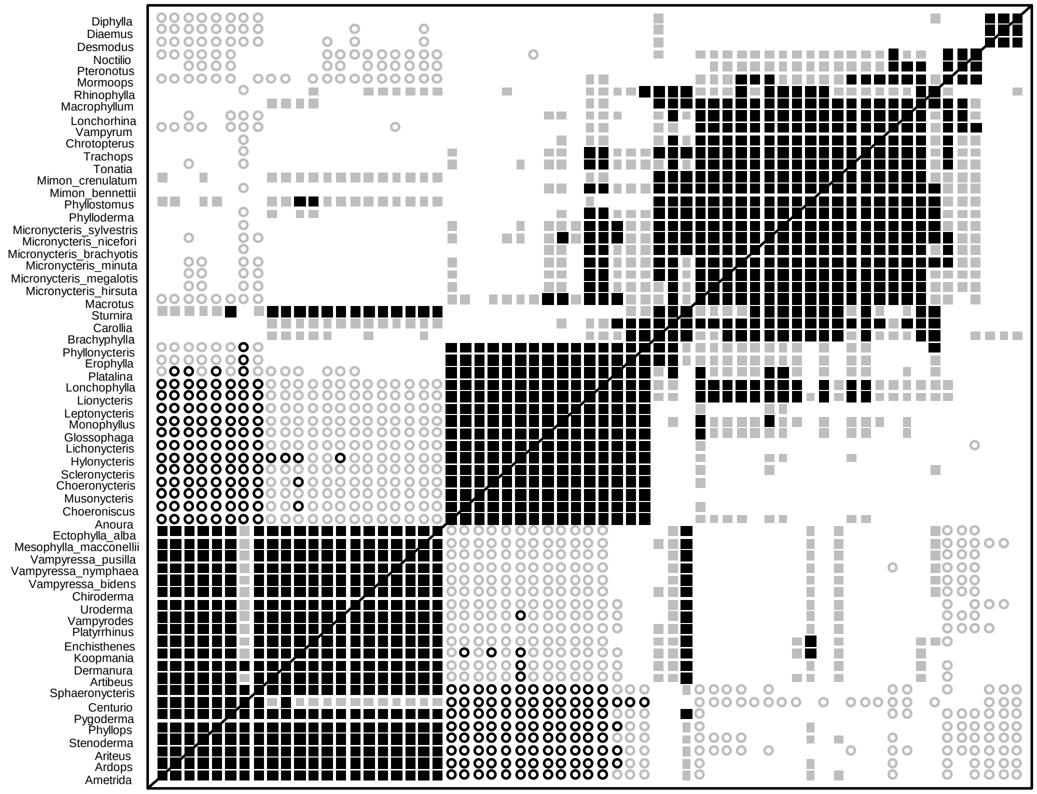


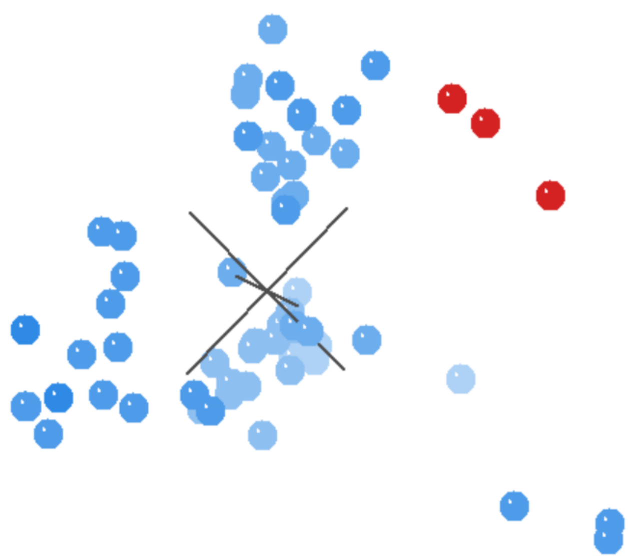
Order Chiroptera
Family Mormoopidae

Published taxa	17
Published characters	209
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	17
Characters used for calculations	162
Median bootstrap value	92
F_{90}	0.54
Stress of 3D MDS	0.19
k_{min}	7
Conclusion	MB

Notes: BDC reveals very little correlation between genera. *Pteronotus* appears to be a well-defined monobaramin in the BDC results. MDS reveals a distinction between ingroup and outgroup taxa, but both are diffuse and poorly clustered. We may provisionally accept *Pteronotus* as a monobaramin. Clear discontinuity is not evident.

Wetterer, A.L., M.V. Rockman, and N.B. Simmons. 2000. Phylogeny of phyllostomid bats (Mammalia: Chiroptera): data from diverse morphological systems, sex chromosomes, and restriction sites. *Bulletin of the American Museum of Natural History* 248:1-200.
Characters: Craniodental, postcranial, soft issue, karyotype, restriction sites



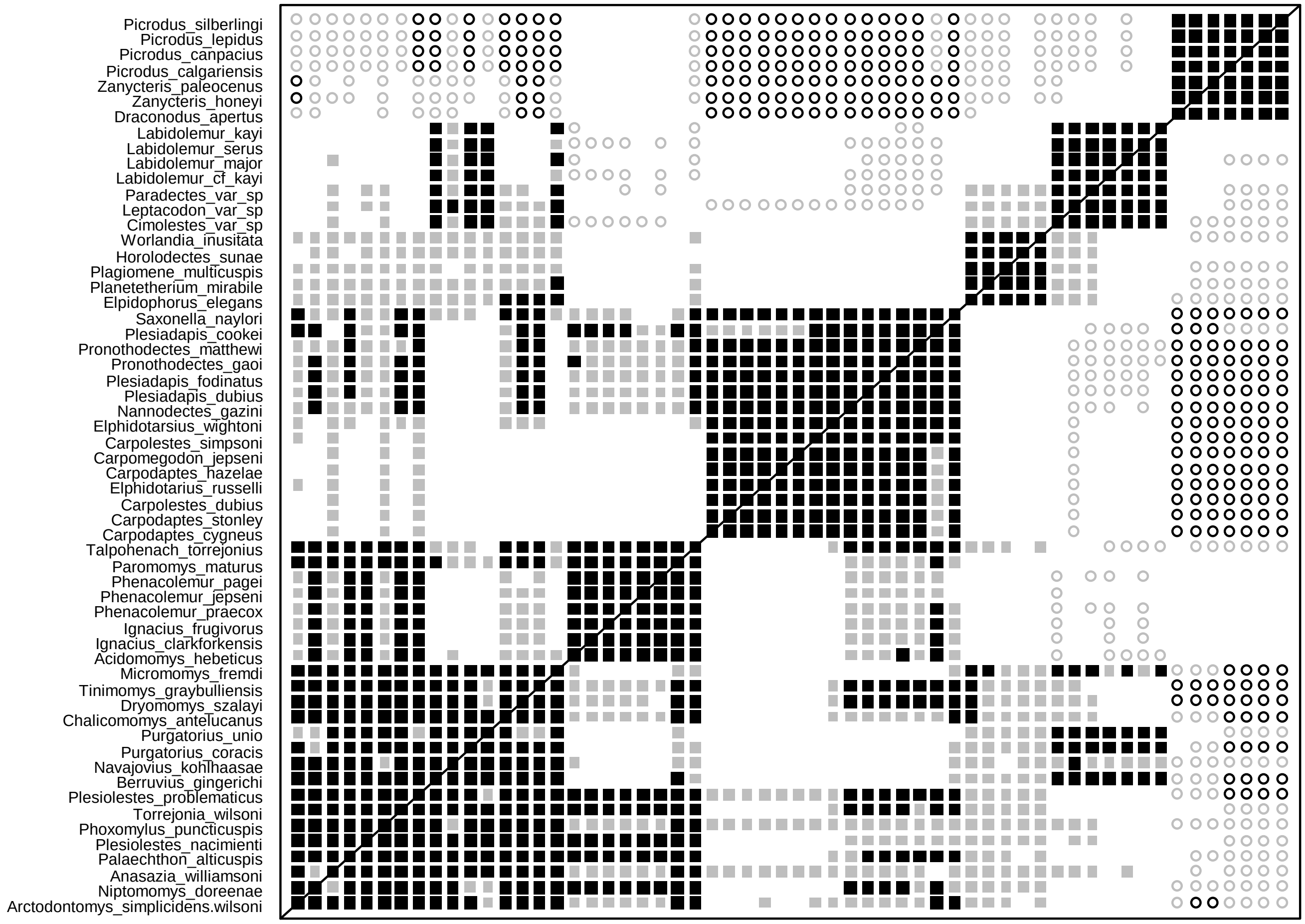


Order Chiroptera
Family Phyllostomidae

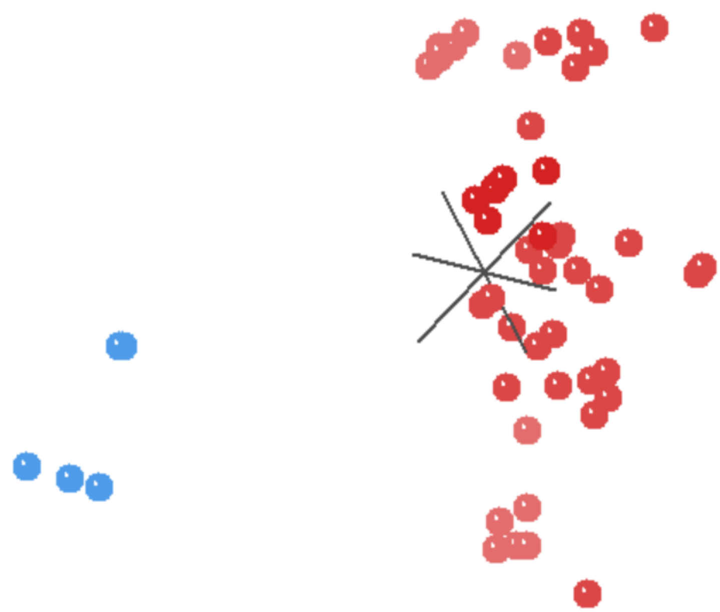
Published taxa	63
Published characters	150
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	63
Characters used for calculations	98
Median bootstrap value	77
F_{90}	0.33
Stress of 3D MDS	0.24
k_{min}	10
Conclusion	Inc

Notes: No clear evidence of discontinuity in BDC or MDS results.

Burger, B.J. 2013. A new species of the archaic primate *Zanycteris* from the late Paleocene of western Colorado and the phylogenetic position of the family Picrodontidae. *PeerJ* 1:e191.
Characters: Dental



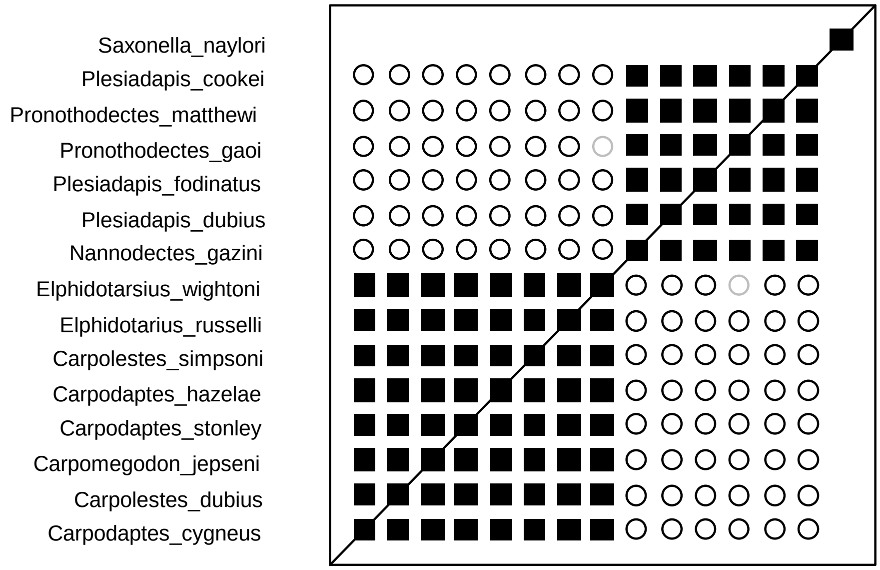
Order Primates
Family Picrodontidae

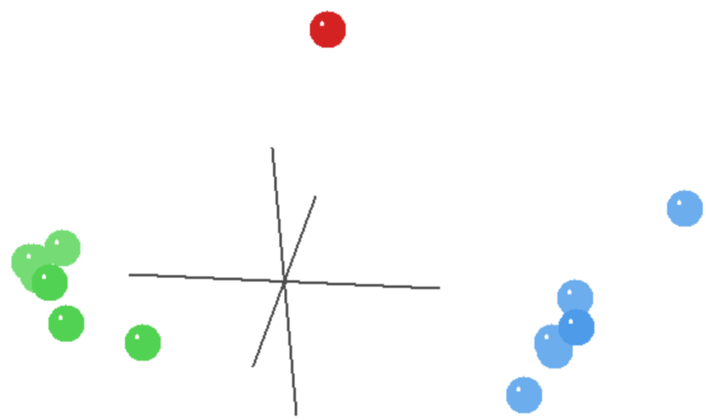


Published taxa	58
Published characters	113
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	58
Characters used for calculations	98
Median bootstrap value	79
F_{90}	0.34
Stress of 3D MDS	0.24
k_{min}	7
Conclusion	HB

Notes: The taxa are trimmed to include Picrodontidae, with Plesiadapidae, and Carpolestidae as the outgroup. Picrodontidae is well-separated from the outgroup taxa in both BDC and MDS results. Picrodontidae is probably a holobaramin.

Burger, B.J. 2013. A new species of the archaic primate *Zanycteris* from the late Paleocene of western Colorado and the phylogenetic position of the family Picrodontidae. *PeerJ* 1:e191.
Characters: Dental





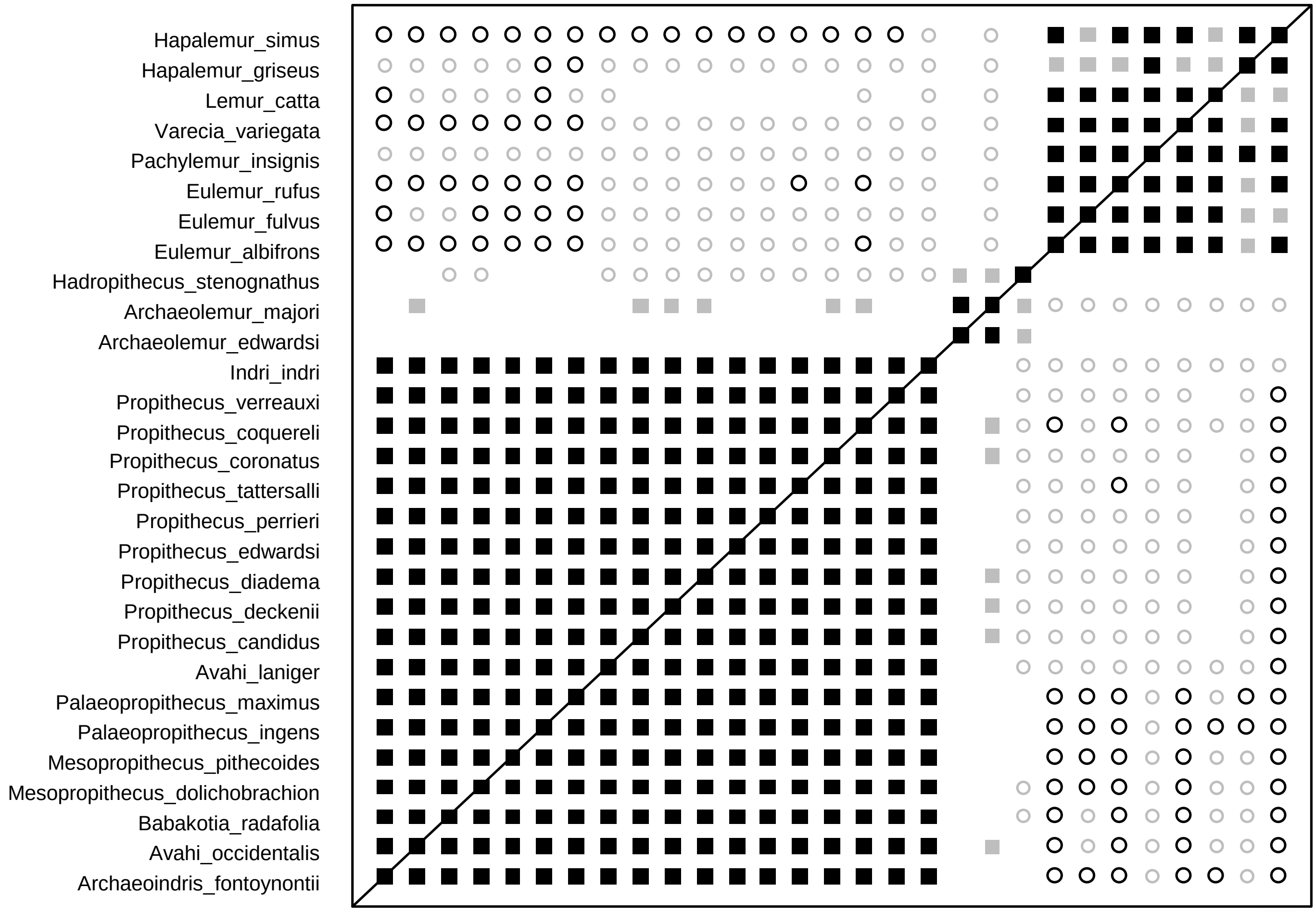
Order Primates
Family Plesiadapidae

Green: Carpolestidae
Blue: Plesiadapidae
Red: *Saxonella*

Published taxa	58
Published characters	113
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	15
Characters used for calculations	110
Median bootstrap value	100
F_{90}	0.86
Stress of 3D MDS	0.09
k_{min}	4
Conclusion	HB

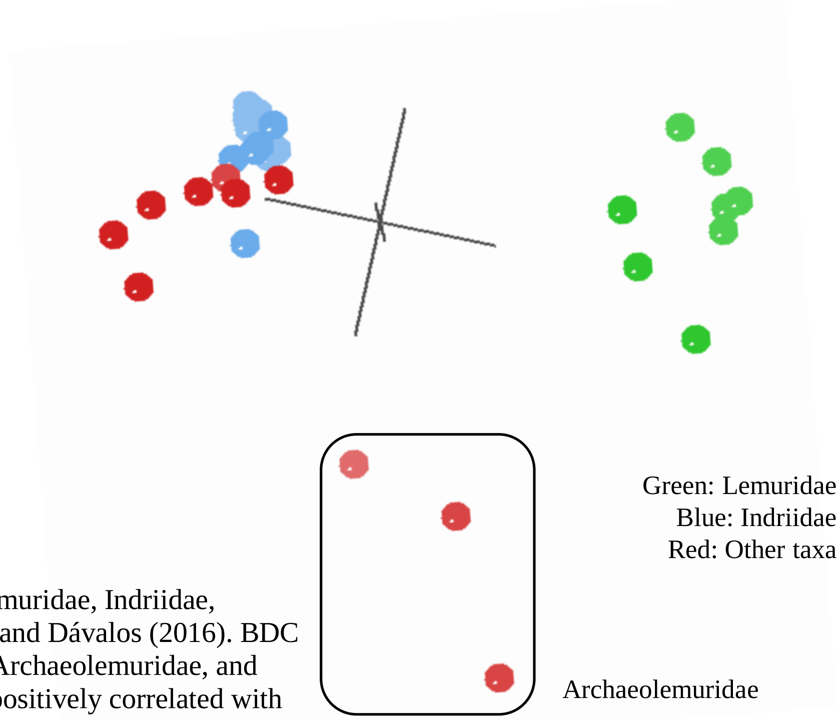
Notes: Taxa from the previous analysis are further subdivided to remove the picrotontids. Plesiadapidae and Carpolestidae are well separated from each other and from the outgroup *Saxonella* in BDC and MDS results. Both are likely holobaramins.

Herrera, J.P. and L.M. Dávalos. 2016. Phylogeny and divergence times of lemurs inferred with recent and ancient fossils in the tree. *Systematic Biology* 65:772-791.
Characters: Craniodental and postcranial



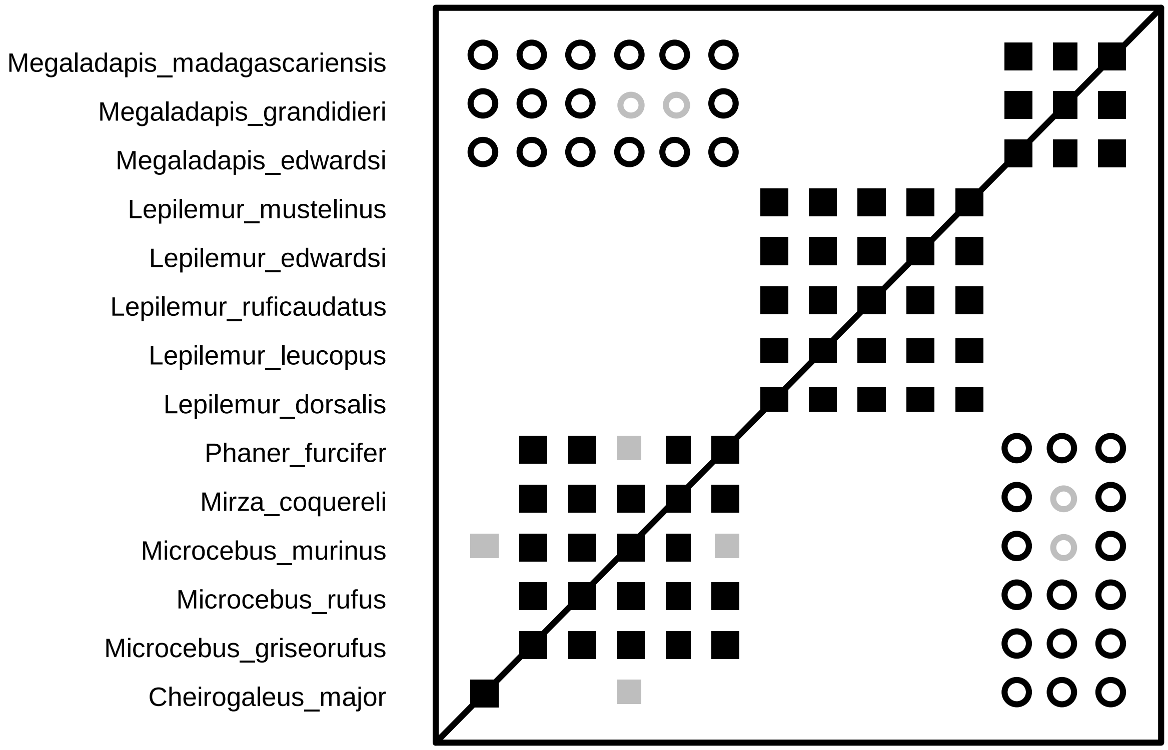
Order Primates
Family Lemuridae

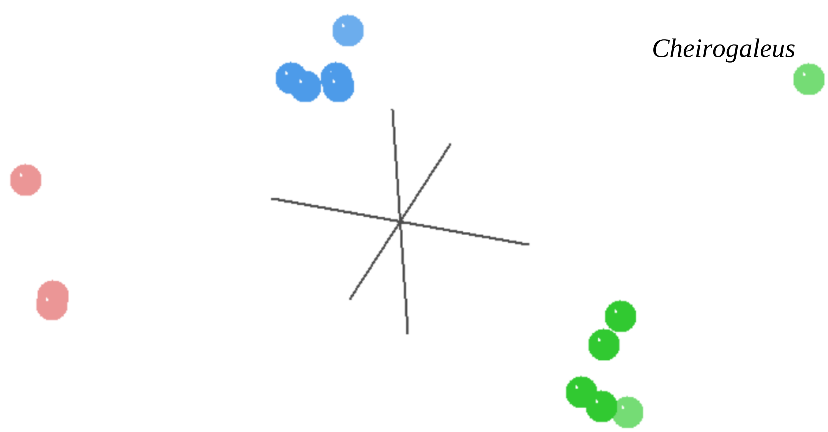
Published taxa	29
Published characters	421
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	29
Characters used for calculations	157
Median bootstrap value	98
F_{90}	0.67
Stress of 3D MDS	0.23
k_{min}	11
Conclusion	HB



Notes: Taxon sample has been trimmed here to include Lemuridae, Indriidae, Palaeopropithecidae, and Archaeolemuridae from Herrera and Dávalos (2016). BDC reveals three groups of taxa corresponding to Lemuridae, Archaeolemuridae, and Indriidae + Palaeopropithecidae. *Archaeolemur majori* is positively correlated with six members of the Indriidae + Palaeopropithecidae group, but all but one BDC with *Archaeolemur majori* have poor bootstrap values. All comparisons between the groups Lemuridae and Indriidae + Palaeopropithecidae share significant, negative BDC. The MDS results support the three groups observed in the BDC, but *Archaeolemur majori* is clearly separated from the Indriidae + Palaeopropithecidae. Hence we may conclude that Lemuridae and Indriidae + Palaeopropithecidae are both likely holobaramins.

Herrera, J.P. and L.M. Dávalos. 2016. Phylogeny and divergence times of lemurs inferred with recent and ancient fossils in the tree. *Systematic Biology* 65:772-791.
Craniodental and postcranial





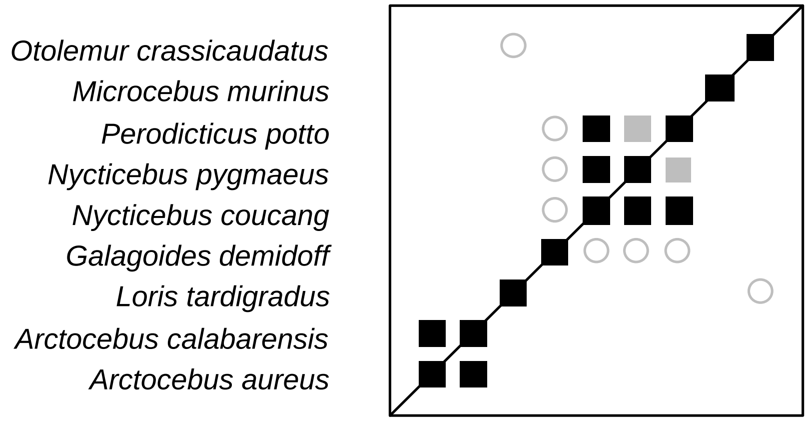
Order Primates
Family Lepilemuridae

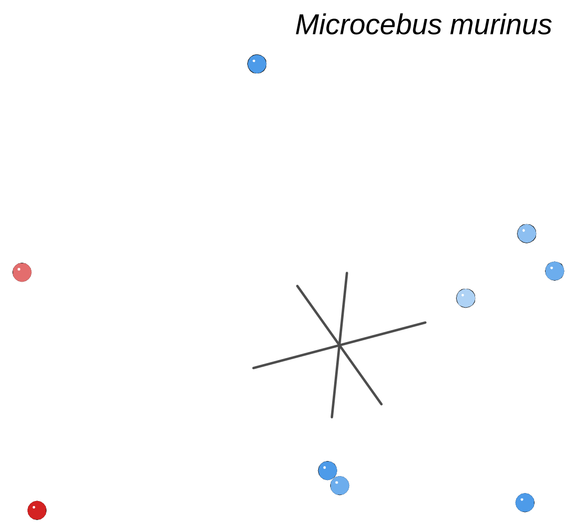
Published taxa	14
Published characters	421
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	14
Characters used for calculations	161
Median bootstrap value	93
F_{90}	0.575
Stress of 3D MDS	0.16
k_{min}	7
Conclusion	HB

Red: Megaladapidae
Green: Cheirogaleidae
Blue: Lepilemuridae

Notes: Taxa have been trimmed to include Lepilemuridae, Cheirogaleidae, and Megaladapidae. BDC reveals three clear groups corresponding to the three families. MDS confirms these three groups. The position of *Cheirogaleus major* is uncertain in both BDC and MDS results. Lepilemuridae and Cheirogaleidae (excluding *Cheirogaleus major*) are likely holobaramins.

Masters, J.C., N.M. Anthony, M.J. De Wit, and A. Mitchell. 2005. Reconstructing the evolutionary history of the Lorisidae using morphological, molecular, and geological data. *American Journal of Physical Anthropology* 127:465-480.
Characters: Craniodental



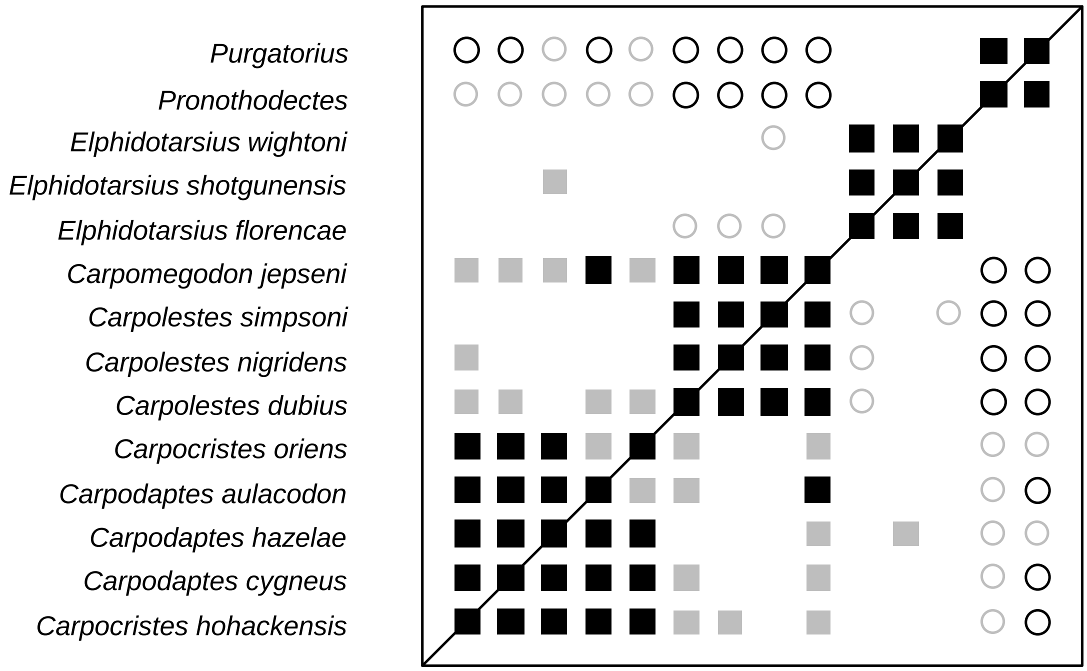


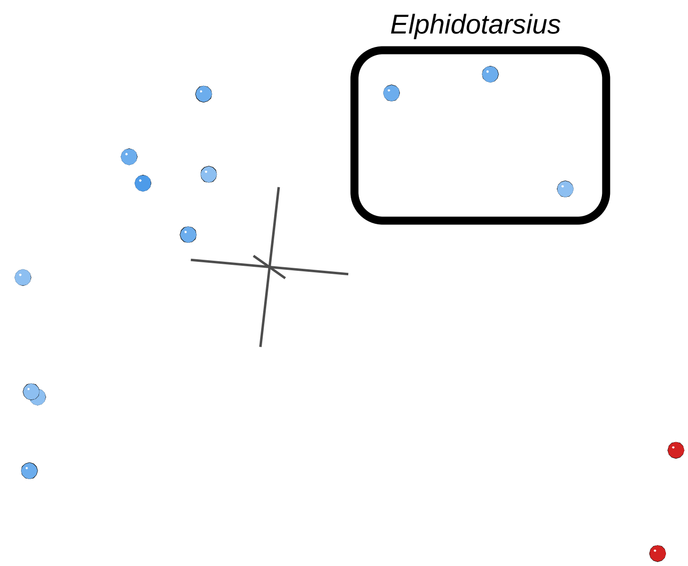
Order Primates
Family Loridae

Published taxa	9
Published characters	36
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	9
Characters used for calculations	36
Median bootstrap value	95.5
F_{90}	0.64
Stress of 3D MDS	0.07
k_{min}	4
Conclusion	Inc

Notes: BDC has few correlations, and MDS results show a diffuse cluster of taxa. No clear evidence of discontinuity is present.

Bloch, J.I., D.C. Fisher, K.D. Rose, and P.D. Gingerich. 2001. Stratocladistic analysis of Paleocene Carpolestidae (Mammalia, Plesiadapiformes) with description of a new late Tiffanian genus. *Journal of Vertebrate Paleontology* 21:119-131.
Characters: Dental



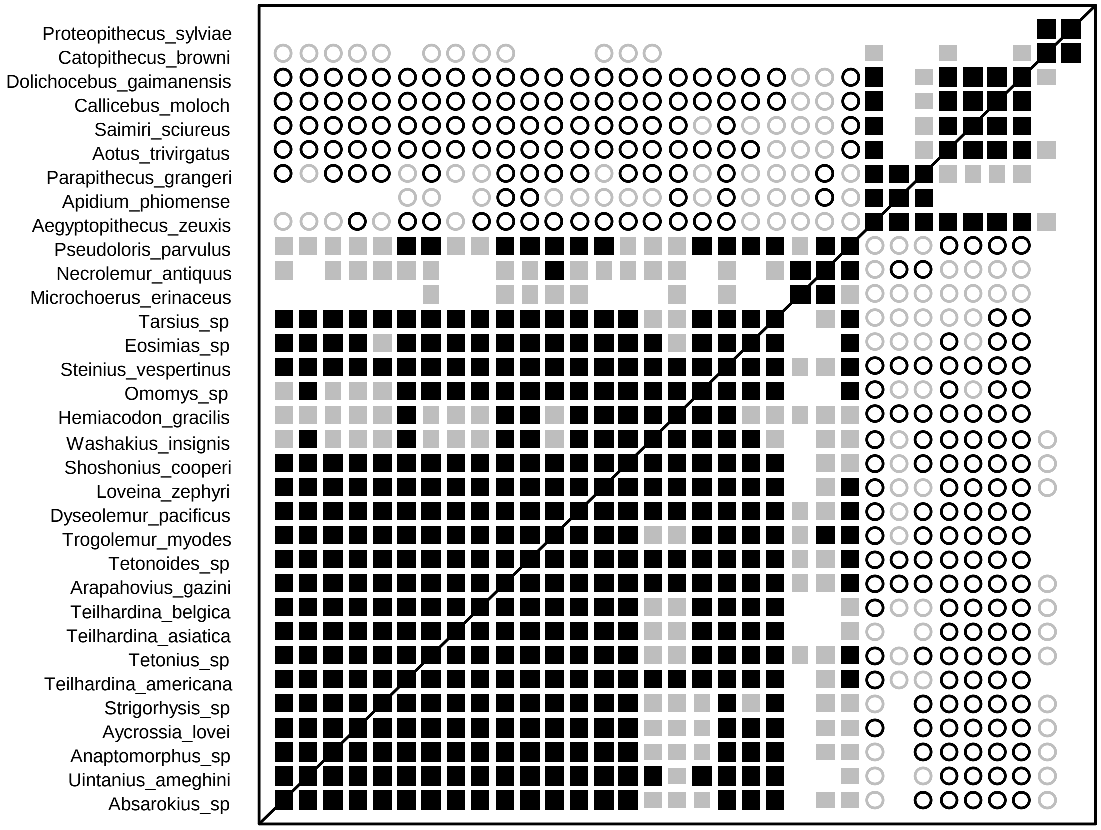


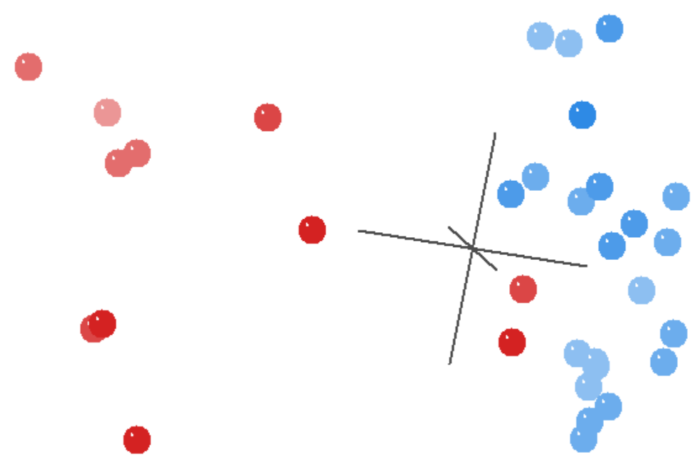
Order Primates
Family Carpolestidae

Published taxa	15
Published characters	33
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	14
Characters used for calculations	30
Median bootstrap value	88
F_{90}	0.46
Stress of 3D MDS	0.09
k_{min}	4
Conclusion	HB?

BDC reveals three groups: outgroup taxa, genus *Elphidotarsius*, and the remaining carpolestids. Significant, negative BDC occurs between the outgroup and the remaining carpolestids but not between the outgroup and *Elphidotarsius*. There is very little significant BDC between *Elphidotarsius* and the remaining carpolestids, and none have bootstrap values >90%. MDS results reveal a good separation between the outgroup taxa and the Carpolestidae, including *Elphidotarsius*, which is part of an arc of carpolestid taxa. Taken together, MDS and BDC support recognizing Carpolestidae as a provisional holobaramin.

Ni, X., Y. Wang, Y. Hu, and C. Li. 2004. A euprimate skull from the early Eocene of China. *Nature* 427:65-68.
Characters: Craniodental, postcranial, soft tissue



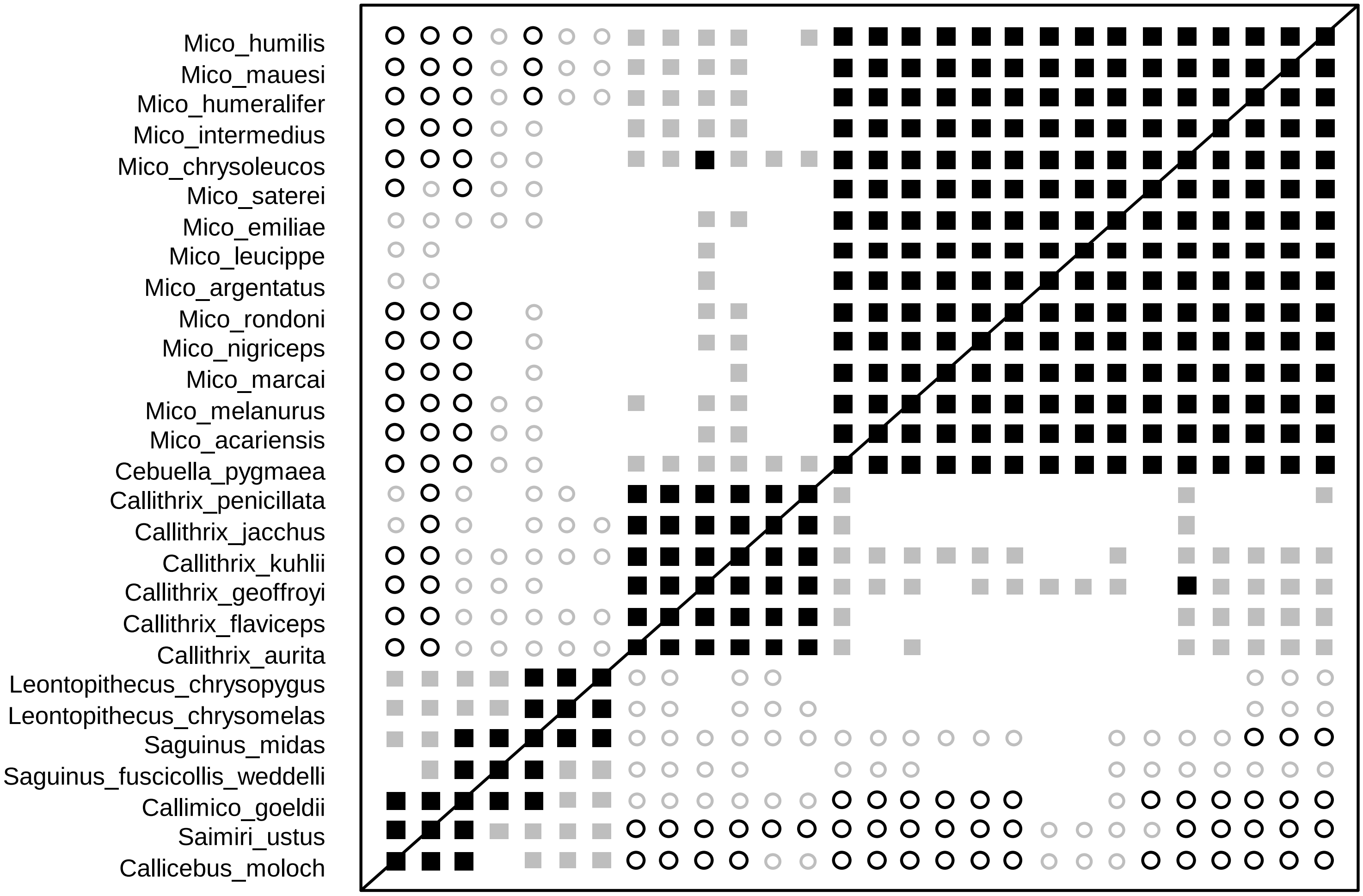


Order Primates
Family Omomyidae

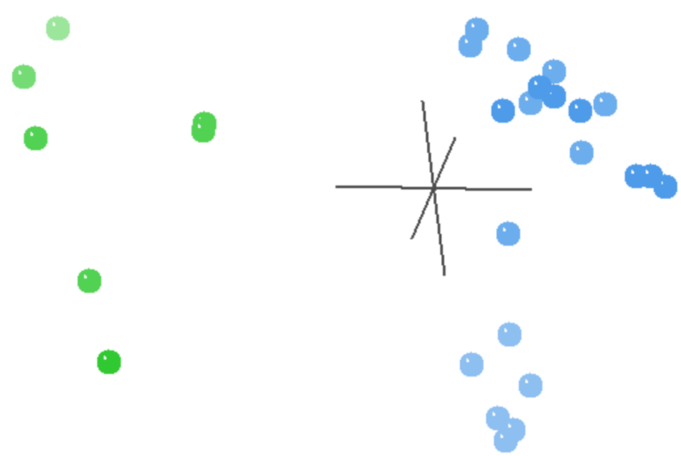
Published taxa	52
Published characters	303
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	33
Characters used for calculations	152
Median bootstrap value	97
F_{90}	0.66
Stress of 3D MDS	0.27
k_{min}	12
Conclusion	HB

Notes: Taxa have been reduced to the Omomyidae and their sister clade, the anthropoids, from Ni et al.'s (2004) phylogeny. Both BDC and MDS reveal a clear distinction between anthropoids and Omomyidae. *Eosimias* and *Tarsius* cluster with Omomyidae in both BDC and MDS results. Omomyidae + *Eosimias* + *Tarsius* is likely a holobaramin.

Garbino, G.S. 2015. How many marmoset (Primates: Cebidae: Callitrichinae) genera are there? A phylogenetic analysis based on multiple morphological systems. *Cladistics* 31:652-678.
Characters: Craniodental, postcranial, soft tissue, vocal



Blue: Callitrichinae
Green: other Cebidae

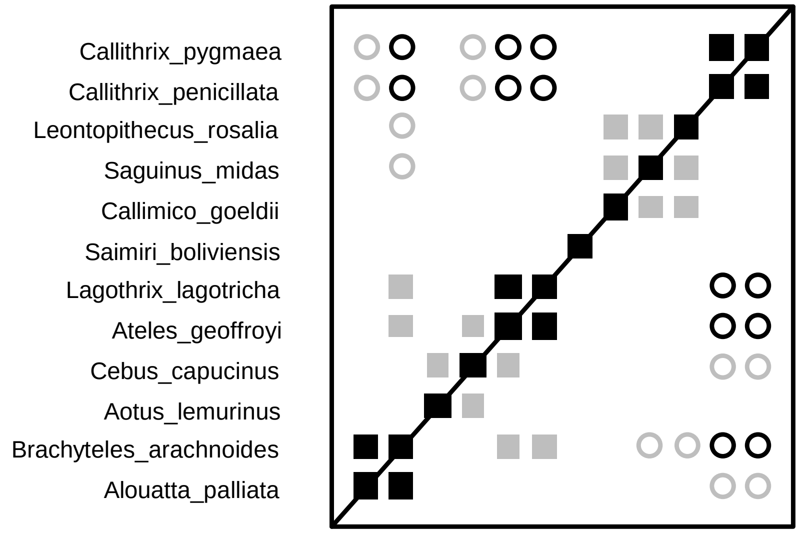


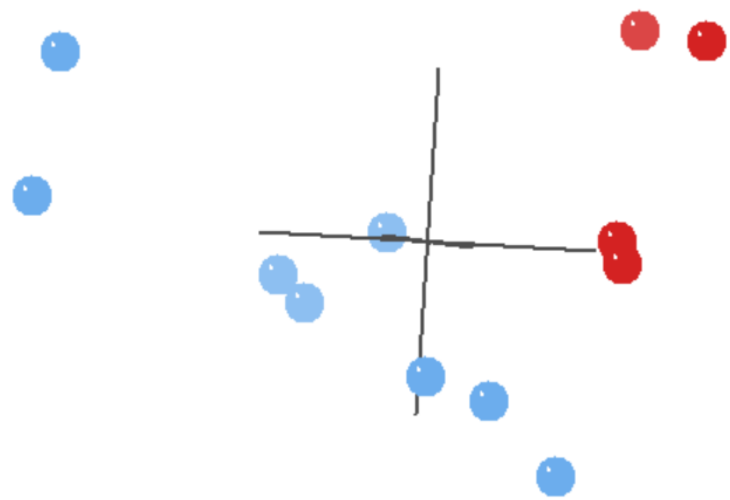
Order Primates
Family Cebidae

Published taxa	28
Published characters	83
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	28
Characters used for calculations	76
Median bootstrap value	83.5
F_{90}	0.46
Stress of 3D MDS	0.14
k_{min}	7
Conclusion	HB?

Notes: BDC and MDS reveal two clear groups: Callitrichinae and the rest of the cebids. This suggests that Callitrichinae is a holobaramin.

Schrago, C.G., B. Mello, and A.E.R. Soares. 2013. Combining fossil and molecular data to date the diversification of New World Primates. *Journal of Evolutionary Biology* 26:2438-2446.
Characters: Craniodental



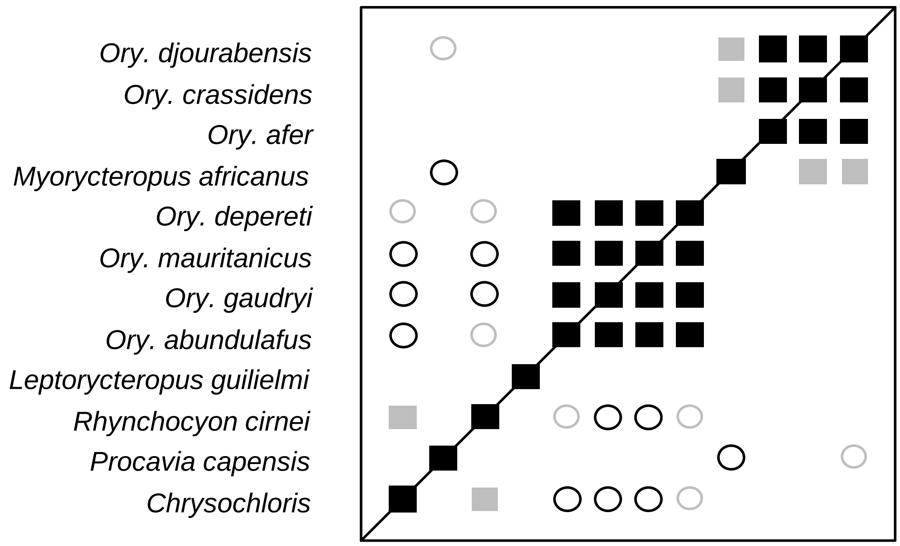


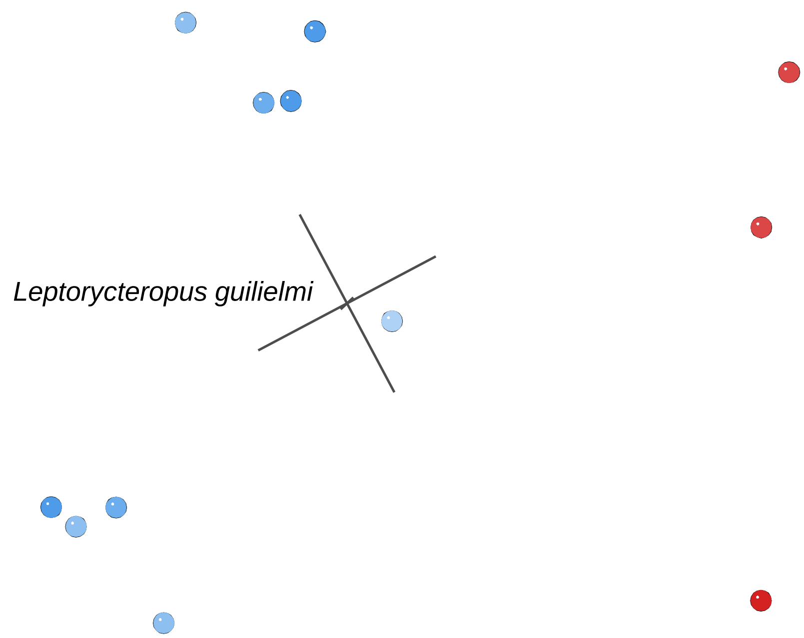
Order Primates
Family Cebidae

Published taxa	31
Published characters	268
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	12
Characters used for calculations	238
Median bootstrap value	97
F_{90}	0.61
Stress of 3D MDS	0.19
k_{min}	9
Conclusion	Inc

Notes: BDC results are poor with few significant correlations. MDS reveals a diffuse cluster of taxa. There is no clear evidence of discontinuity.

Lehmann, T. 2009. Phylogeny and systematics of the Orycteropodidae (Mammalia, Tubulidentata). *Zoological Journal of the Linnean Society* 155:649-702.
Characters: Craniodental and postcranial



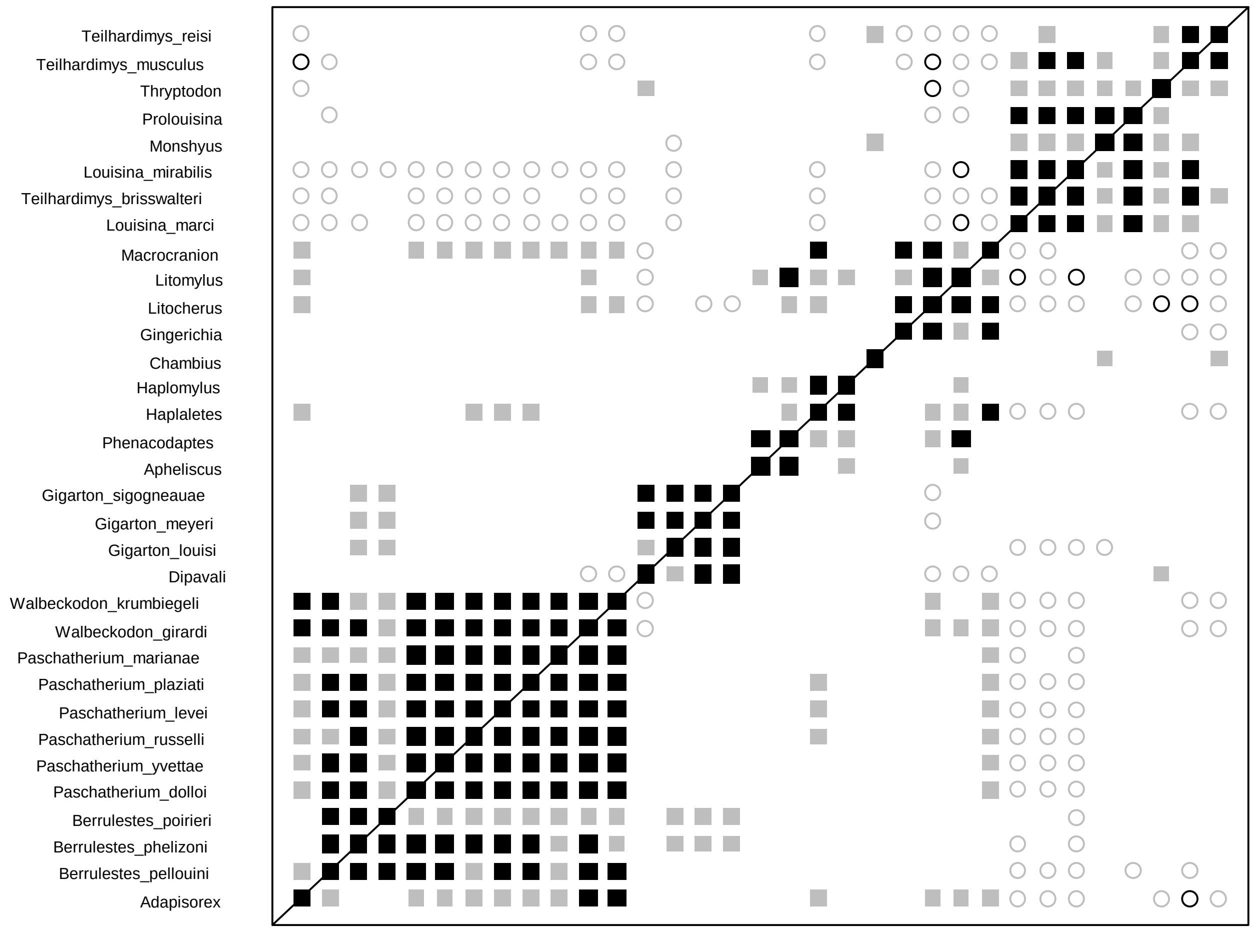


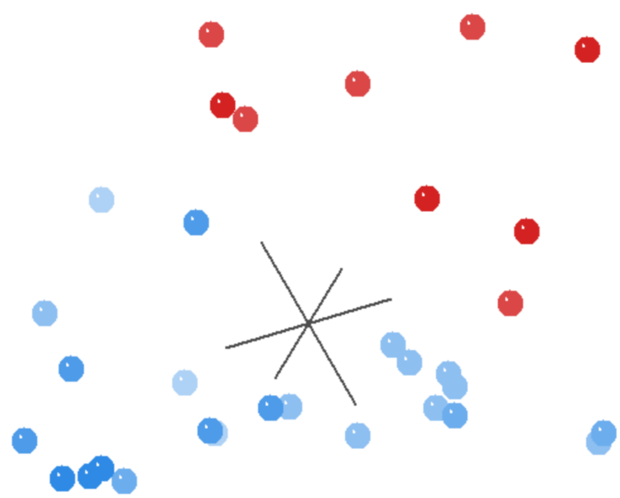
Order Tubilidentata
Family Orycteropodidae

Published taxa	12
Published characters	39
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	12
Characters used for calculations	32
Median bootstrap value	89.5
F_{90}	0.47
Stress of 3D MDS	0.13
k_{min}	3
Conclusion	Inc

Notes: BDC results reveal two groups of orycteropids with sporadic negative BDC with outgroup taxa. MDS reveals a highly diffuse group of orycteropids that are separated from the outgroup. There is little conclusive evidence of discontinuity or continuity among the orycteropids.

Hooker, J.J. and D.E. Russell. 2012. Early Palaeogene Louisinidae (Macroscelidea, Mammalia), their relationships and north European diversity. *Zoological Journal of the Linnean Society* 164:856-936.
Characters: Craniodental and postcranial



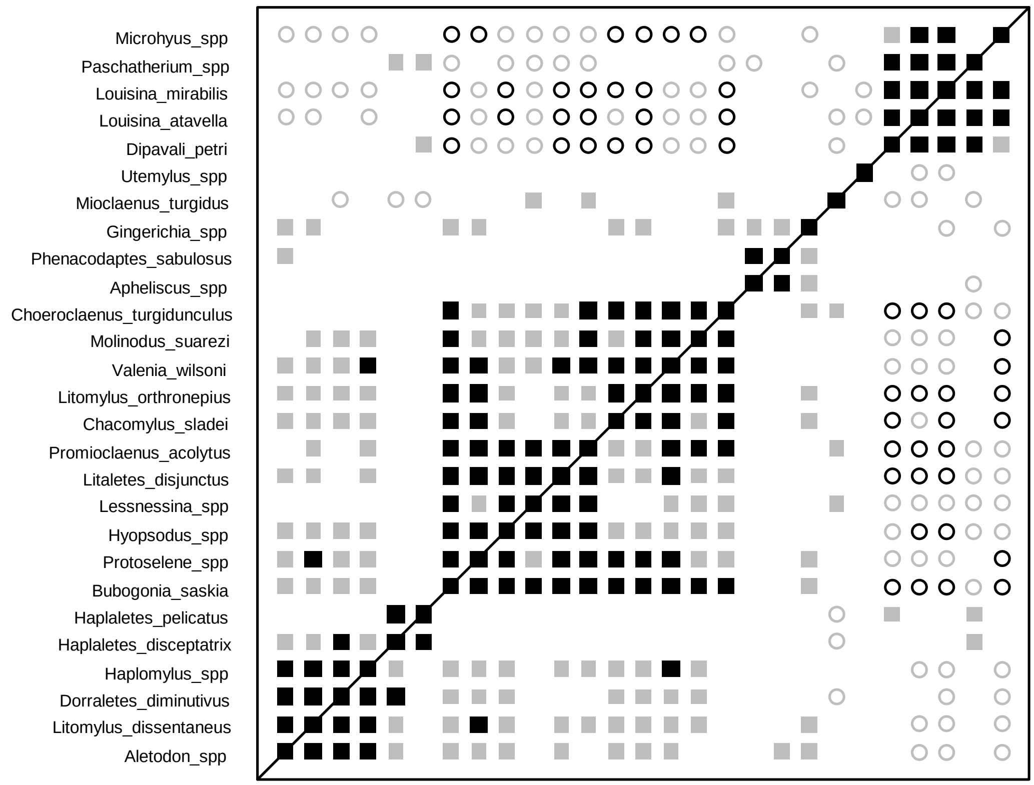


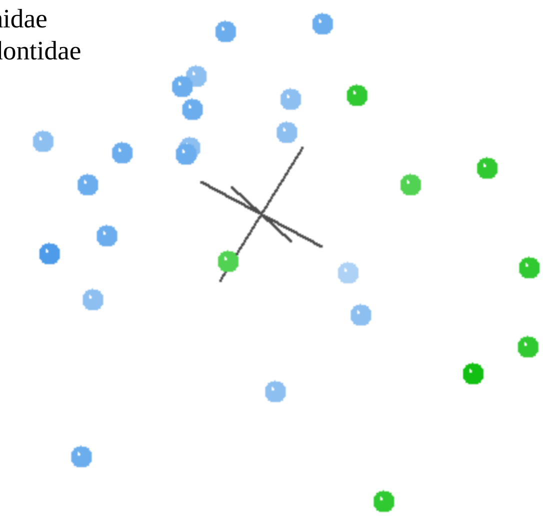
Order Condylarthra
Family Louisinidae

Published taxa	37
Published characters	89
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	37
Characters used for calculations	67
Median bootstrap value	79
F_{90}	0.19
Stress of 3D MDS	0.14
k_{min}	5
Conclusion	Inc

Notes: BDC implies discontinuity within Louisinidae, but no clustering evident in MDS

Williamson, T.E. and A. Weil. 2011. A new Puercan (early Paleocene) hyopsodontid "condylarth" from New Mexico. *Acta Palaeontologica Polonica* 56:247-255.
Characters: Dental and postcranial



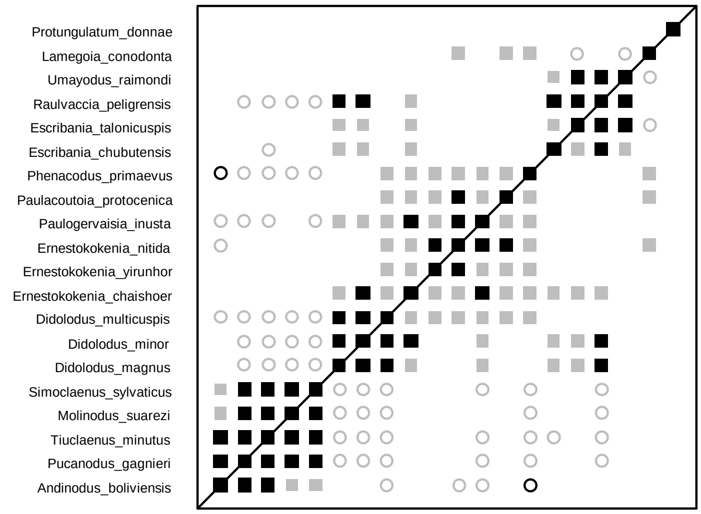


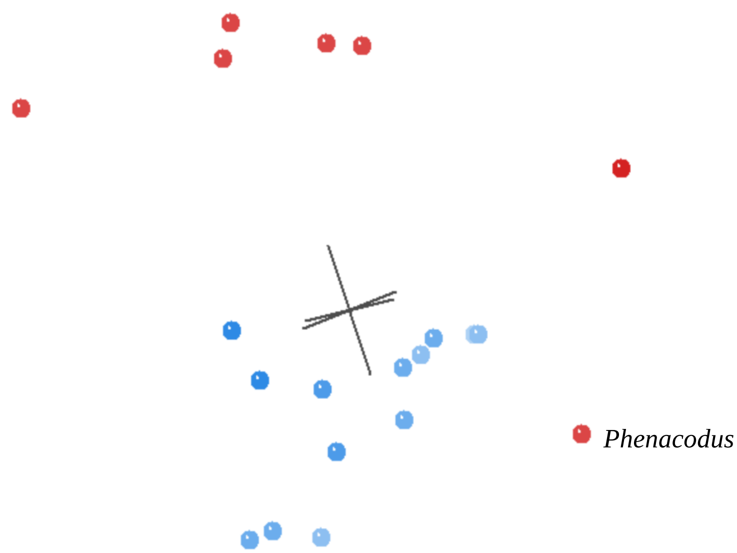
Order Condylarthra
Family Hyopsodontidae

Published taxa	30
Published characters	59
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	27
Characters used for calculations	44
Median bootstrap value	78
F_{90}	0.22
Stress of 3D MDS	0.22
k_{min}	8
Conclusion	Inc

Notes: BDC reveals two groups of taxa, but MDS shows a diffuse cluster. Clear discontinuity is not evident.

Gelfo, J.N. and B. Sigé. 2011. A new didolodontid mammal from the Late Paleocene-Earliest Eocene of Laguna Umayo, Peru. *Acta Palaeontologica Polonica* 56:665-678.
Characters: Dental



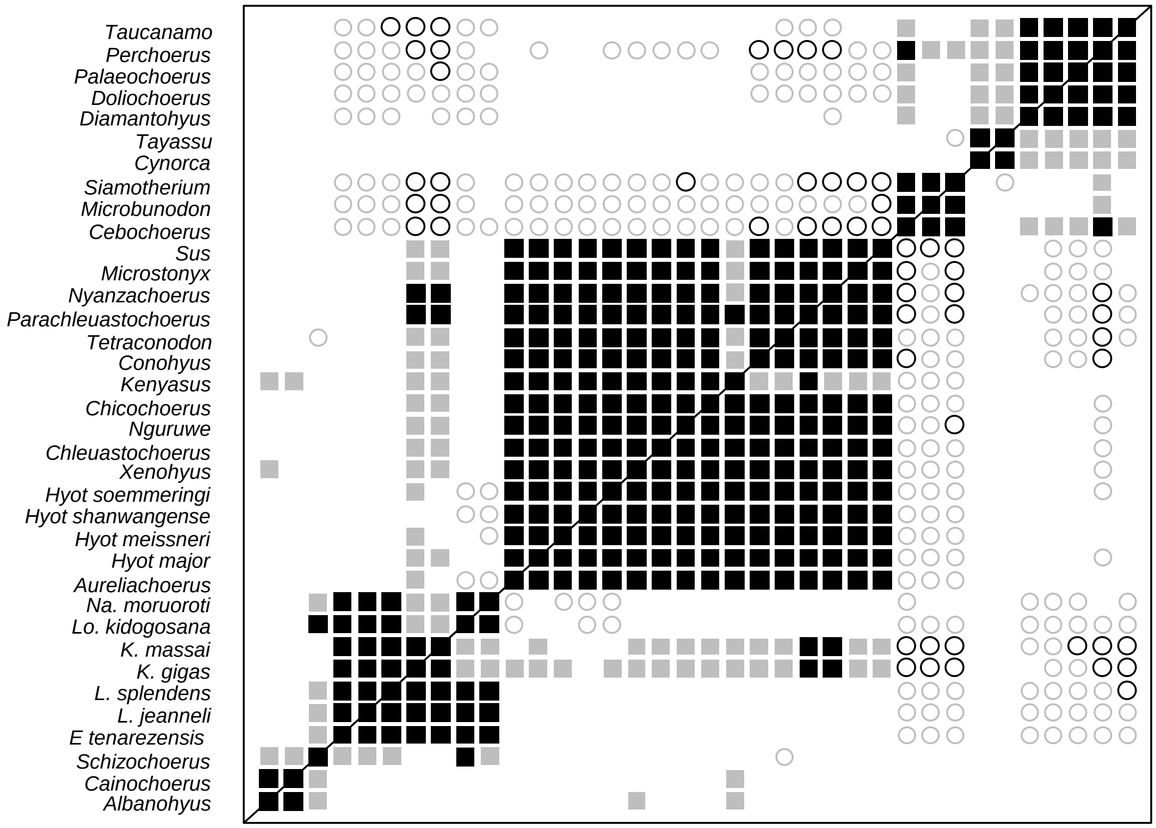


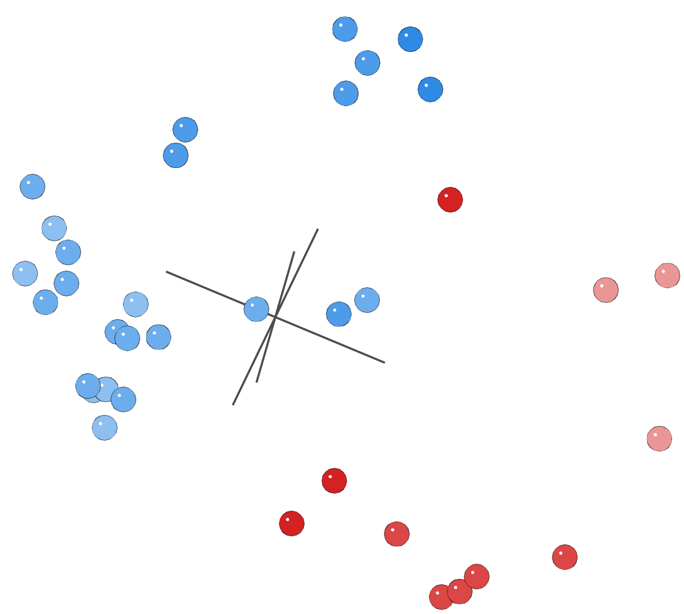
Order Condylarthra
Family Didolodontidae

Published taxa	20
Published characters	41
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	20
Characters used for calculations	25
Median bootstrap value	74
F_{90}	0.13
Stress of 3D MDS	0.2
k_{min}	5
Conclusion	HB?

Notes: Didolodontidae is well separated from the outgroup in both BDC and MDS results. *Phenacodus* is also part of the Dipolodontidae in both analyses. Didolodontidae + *Phenacodus* is likely a holobaramin.

Orliac, M.J., A. Pierre-Olivier, and S. Ducrocq. 2010. Phylogenetic relationships of the Suidae (Mammalia, Cetartiodactyla): new insights on the relationships within Suoidea. *Zoologica Scripta* 39:315-330.
Characters: Dental



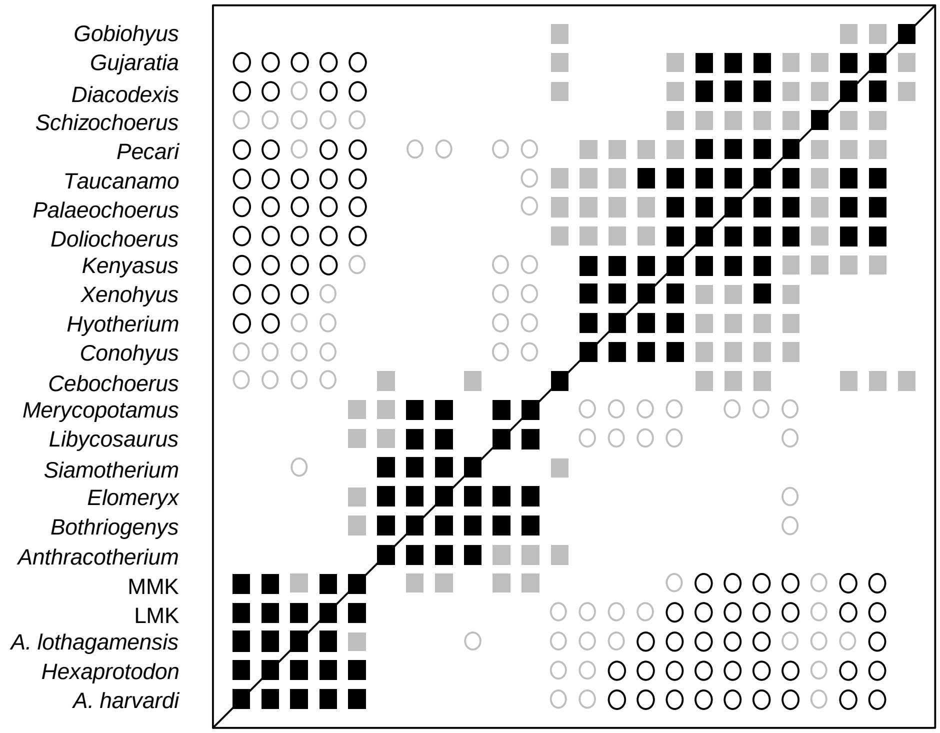


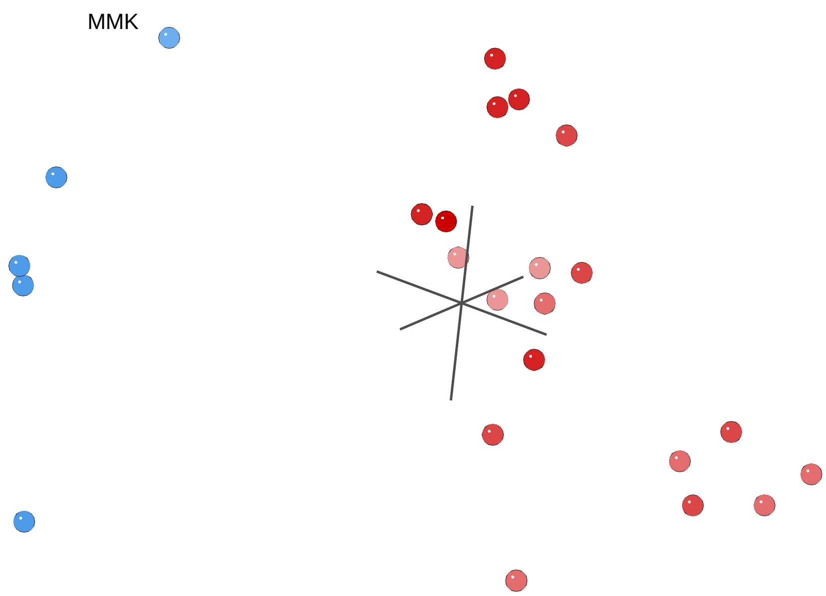
Order Artiodactyla
Family Suidae

Published taxa	41
Published characters	125
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	36
Characters used for calculations	87
Median bootstrap value	79
F_{90}	0.28
Stress of 3D MDS	0.2
k_{min}	8
Conclusion	HB

Notes: BDC supports recognizing Suidae as a holobaramin. MDS is less clear, but the suids are definitely separated from the outgroup taxa.

Boisserie, J.R., F. Lihoreau, M. Orliac, R.E. Fisher, E.M. Weston, and S. Ducrocq. 2010. Morphology and phylogenetic relationships of the earliest known hippopotamids (Cetartiodactyla, Hippopotamidae, Kenyapotaminae). *Zoological Journal of the Linnean Society* 158:325-366.
Characters: Craniodental and postcranial



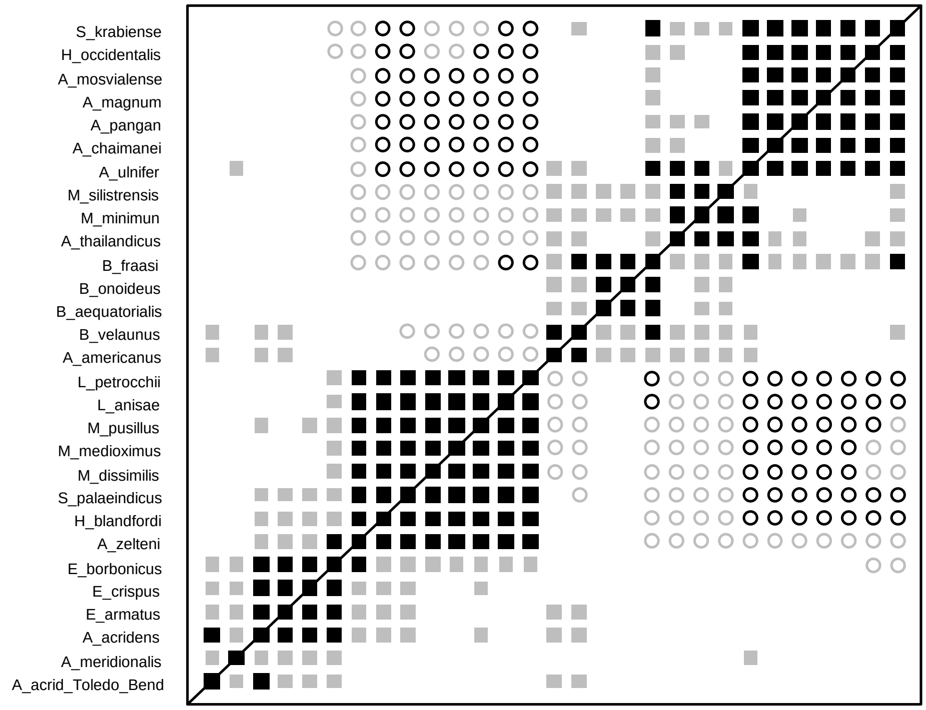


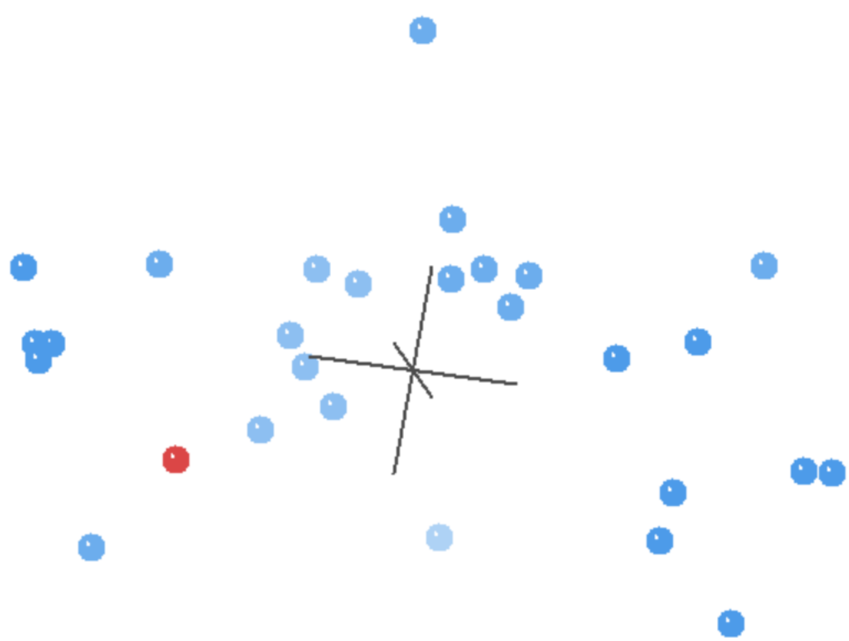
Order Artiodactyla
Family Hippopotamidae

Published taxa	24
Published characters	87
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	24
Characters used for calculations	81
Median bootstrap value	84
F_{90}	0.38
Stress of 3D MDS	0.16
k_{min}	7
Conclusion	HB?

Notes: Both MDS and BDC reveal a distinct cluster of hippopotamids separate from other taxa. In the BDC results, the composite taxon "Middle Miocene Kenyapotamines" (MMK) shares significant, postiive BDC with four outgroup taxa, but the correlations all have low bootstrap values. The MDS results reveal MMK well separated from the outgroup taxa. Thus, Hippopotamidae is probably a holobaramin.

Rincon, A.F., J.I. Bloch, B.J. MacFadden, and C.A. Jaramillo. 2013. First central American record of Anthracotheriidae (Mammalia, Bothriodontinae) from the early Miocene of Panama. *Journal of Vertebrate Paleontology* 33:421-433.
Characters: Craniodental



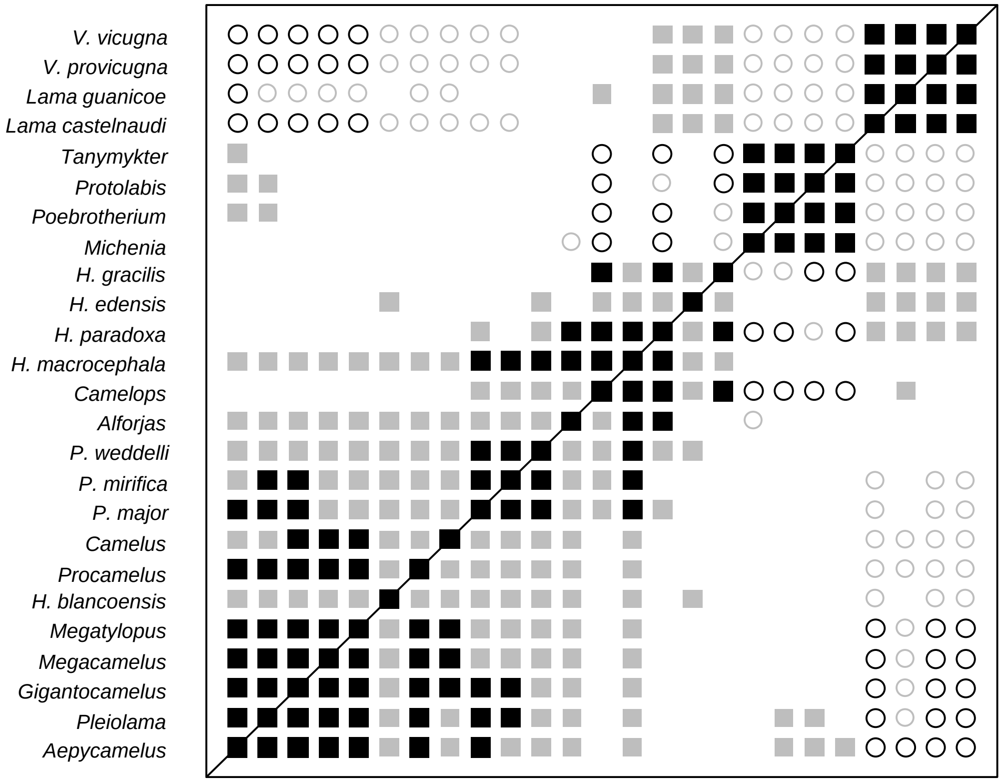


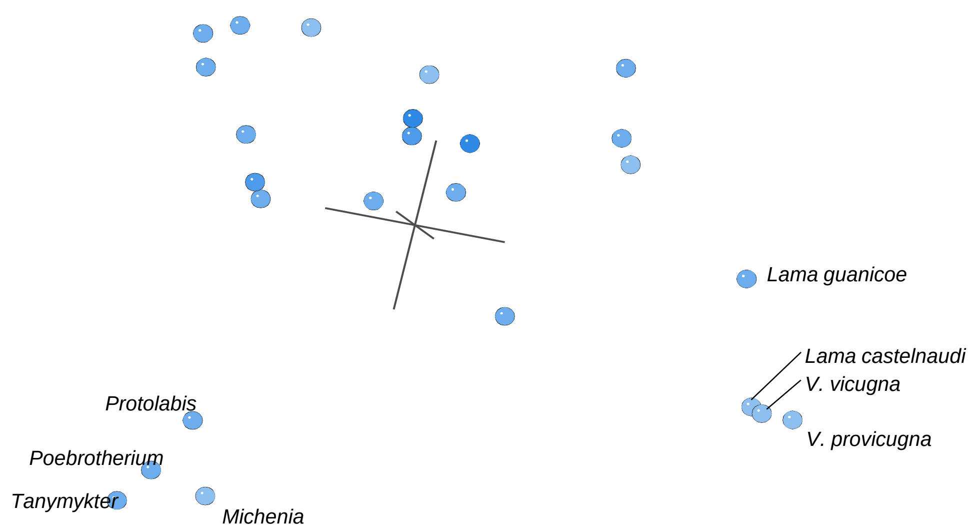
Order Artiodactyla
Family Anthracotheriidae

Published taxa	29
Published characters	51
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	29
Characters used for calculations	41
Median bootstrap value	73
F_{90}	0.28
Stress of 3D MDS	0.15
k_{min}	4
Conclusion	Inc

Notes: No evidence of discontinuity.

Scherer, C.S. 2013. The Camelidae (Mammalia, Artiodactyla) from the Quaternary of South America: cladistic and biogeographic hypotheses. *Journal of Mammalian Evolution* 20:45-56.
Characters: Craniodental and postcranial



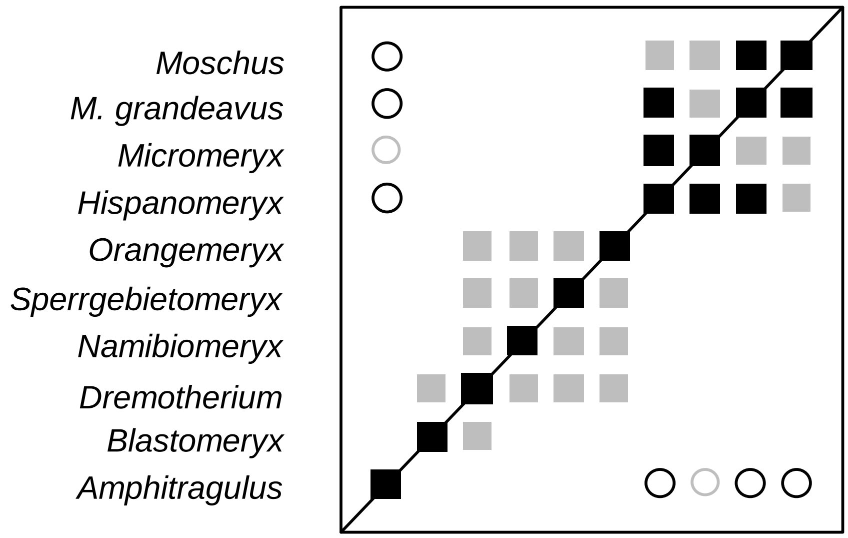


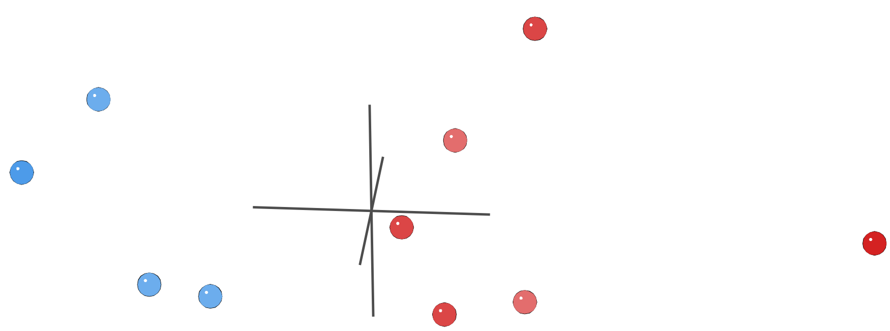
Order Artiodactyla
Family Camelidae

Published taxa	25
Published characters	35
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	10
Characters used for calculations	25
Median bootstrap value	71
F_{90}	0.23
Stress of 3D MDS	0.14
k_{min}	3
Conclusion	HB?

Notes: Somewhat ambiguous BDC, with significant, negative BDC between basal camelids *Protolabis*, *Poebrotherium*, *Tanymykter*, and *Michenia* and the rest of the camelids. MDS reveals clearer evidence of discontinuity, suggesting provisionally that Camelidae *sensu stricto* (excluding basal camelids) is a holobaramin.

Sanchez, I.M., M.S. Domingo, and J. Morales. 2010. The genus *Hispanomeryx* (Mammalia, Ruminantia, Moschidae) and its bearing on musk deer phylogeny and systematics. *Palaeontology* 53:1023-1047.
Characters: Craniodental and postcranial



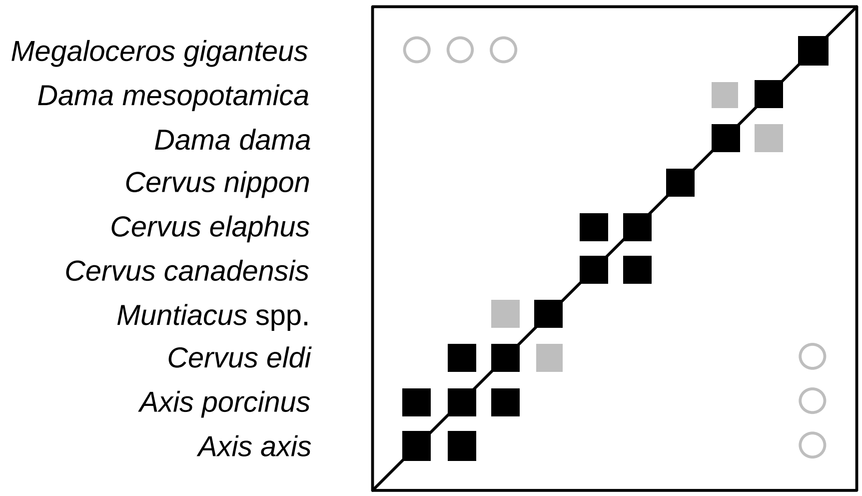


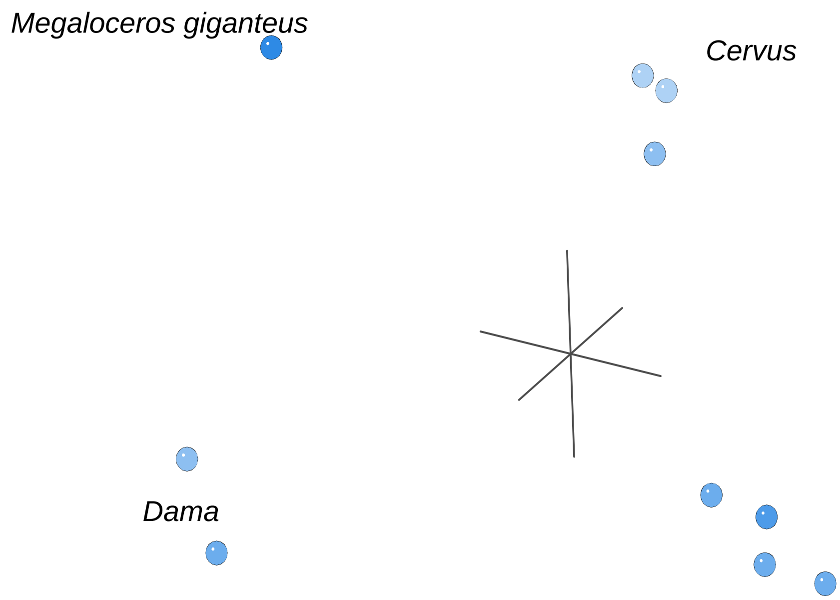
Order Artiodactyla
Family Moschidae

Published taxa	10
Published characters	71
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	10
Characters used for calculations	40
Median bootstrap value	86
F_{90}	0.38
Stress of 3D MDS	0.08
k_{min}	4
Conclusion	MB

Notes: Moschidae is a definite cluster in the BDC results, but there is little significant, negative BDC. MDS shows Moschidae adjacent to outgroup taxa. Moschidae is a monobaramin.

Lister, A.M., C.J. Edwards, D.A.W. Nock, M. Bunce, I.A. Van Pijlen, D.G. Bradley, M.G. Thomas, and I. Barnes. 2005. The phylogenetic position of the 'giant deer' *Megaloceros giganteus*. *Nature* 438:850-853.
Characters: Craniodental and postcranial



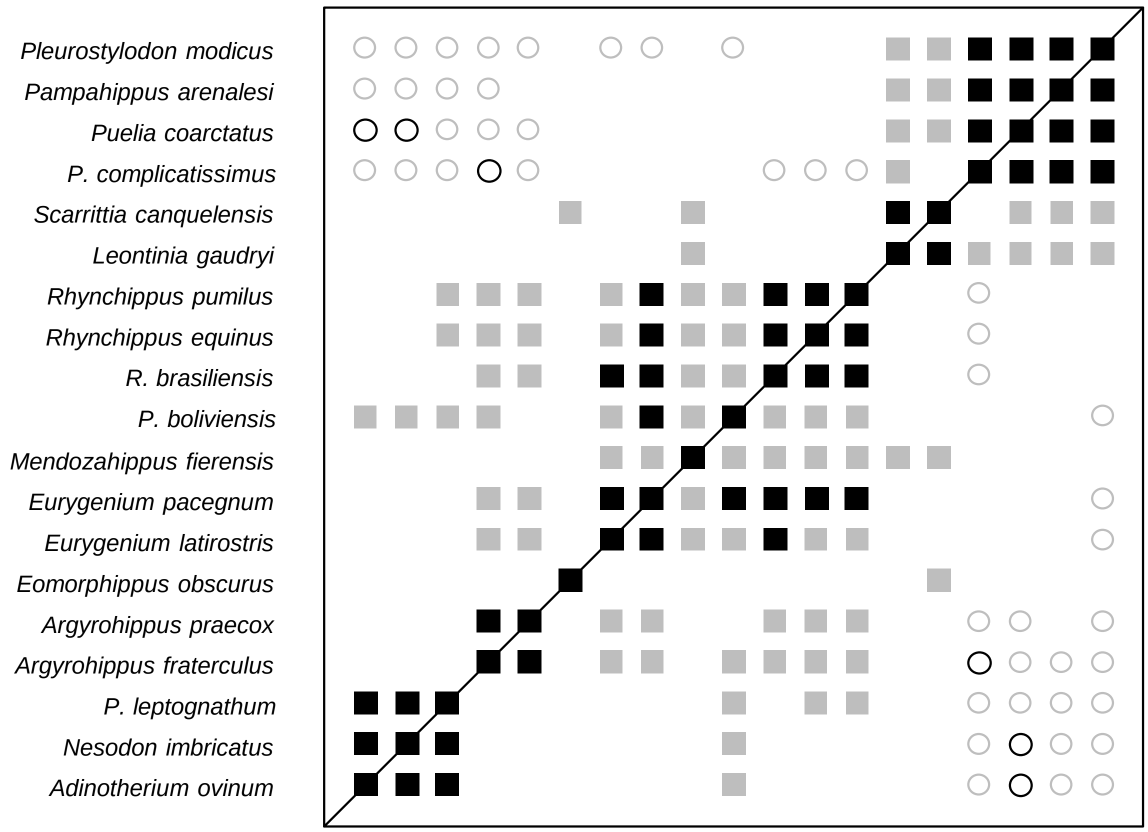


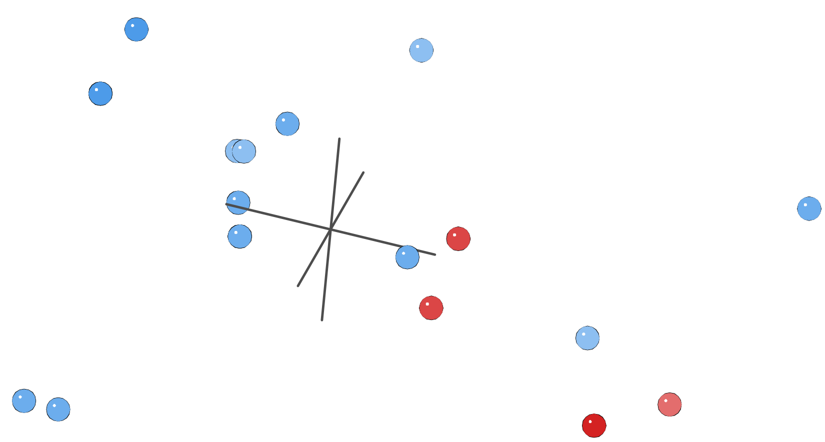
Order Artiodactyla
Family Cervidae

Published taxa	10
Published characters	74
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	10
Characters used for calculations	74
Median bootstrap value	100
F_{90}	0.69
Stress of 3D MDS	0.23
k_{min}	7
Conclusion	Inc

Notes: Very few correlations in BDC, and a diffuse cluster of taxa in MDS. No clear discontinuity is evident.

Cerdeño, E. and B. Vera. 2010. *Mendozahippus fierensis*, gen. et sp. nov., new Notohippidae (Notoungulata) from the late Oligocene of Mendoza (Argentina). *Journal of Vertebrate Paleontology* 30:1805-1817.
Characters: Craniodental and postcranial



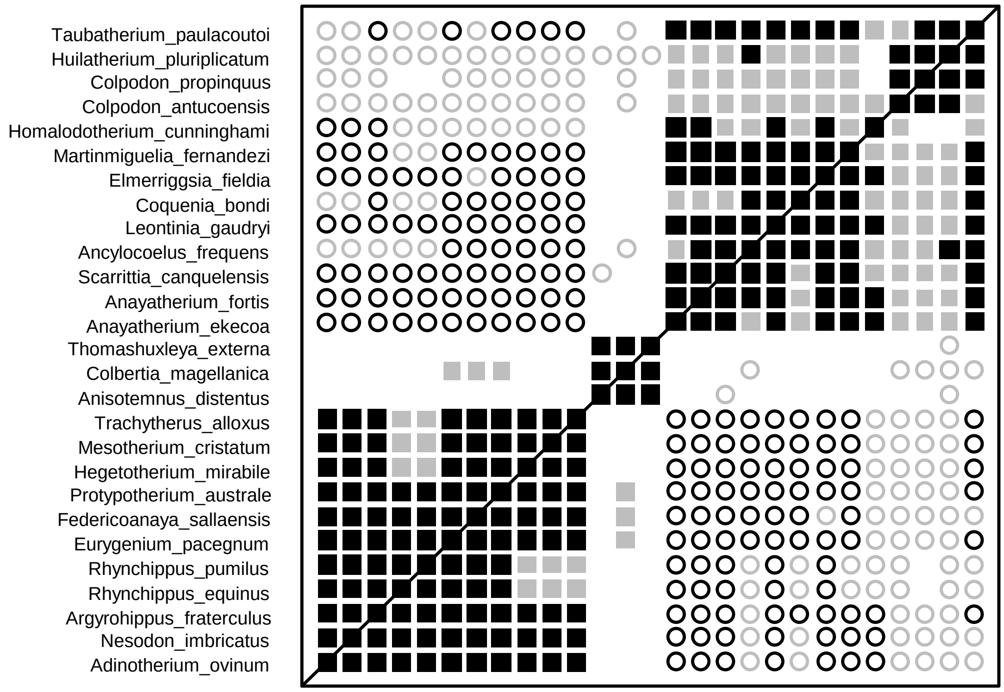


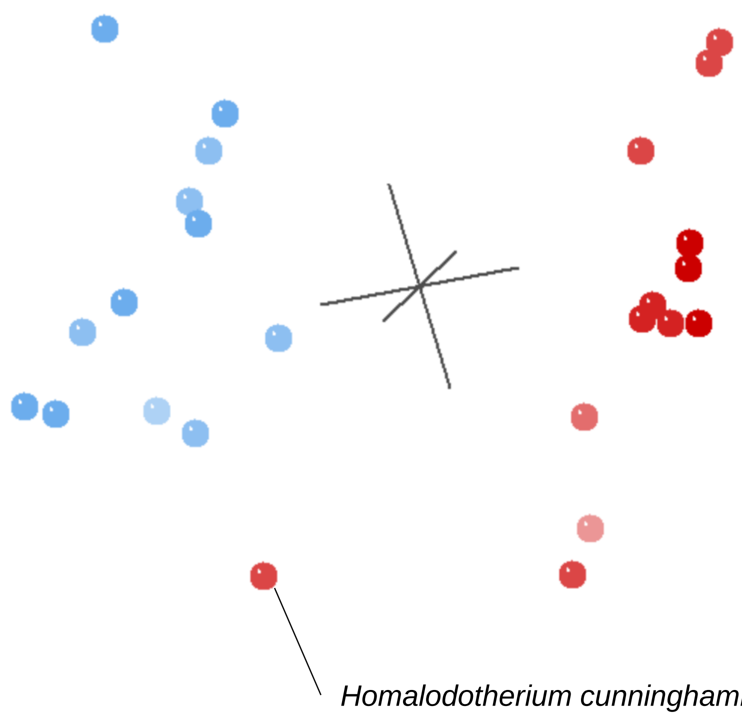
Order Notoungulata
Family Notohippidae

Published taxa	19
Published characters	38
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	19
Characters used for calculations	29
Median bootstrap value	73
F_{90}	0.13
Stress of 3D MDS	0.14
k_{min}	4
Conclusion	Inc

Notes: BDC reveals two groups with substantial overlap, and MDS confirms. No clear discontinuity is evident.

Schockey, B.J., J.J. Flynn, D.A. Croft, P. Gans, and R.A. Wyss. 2012. New leontiniid Notoungulata (Mammalia) from Chile and Argentina: comparative anatomy, character analysis, and phylogenetic hypotheses. *American Museum Novitates* 3737:1-64.
Characters: Craniodental and postcranial



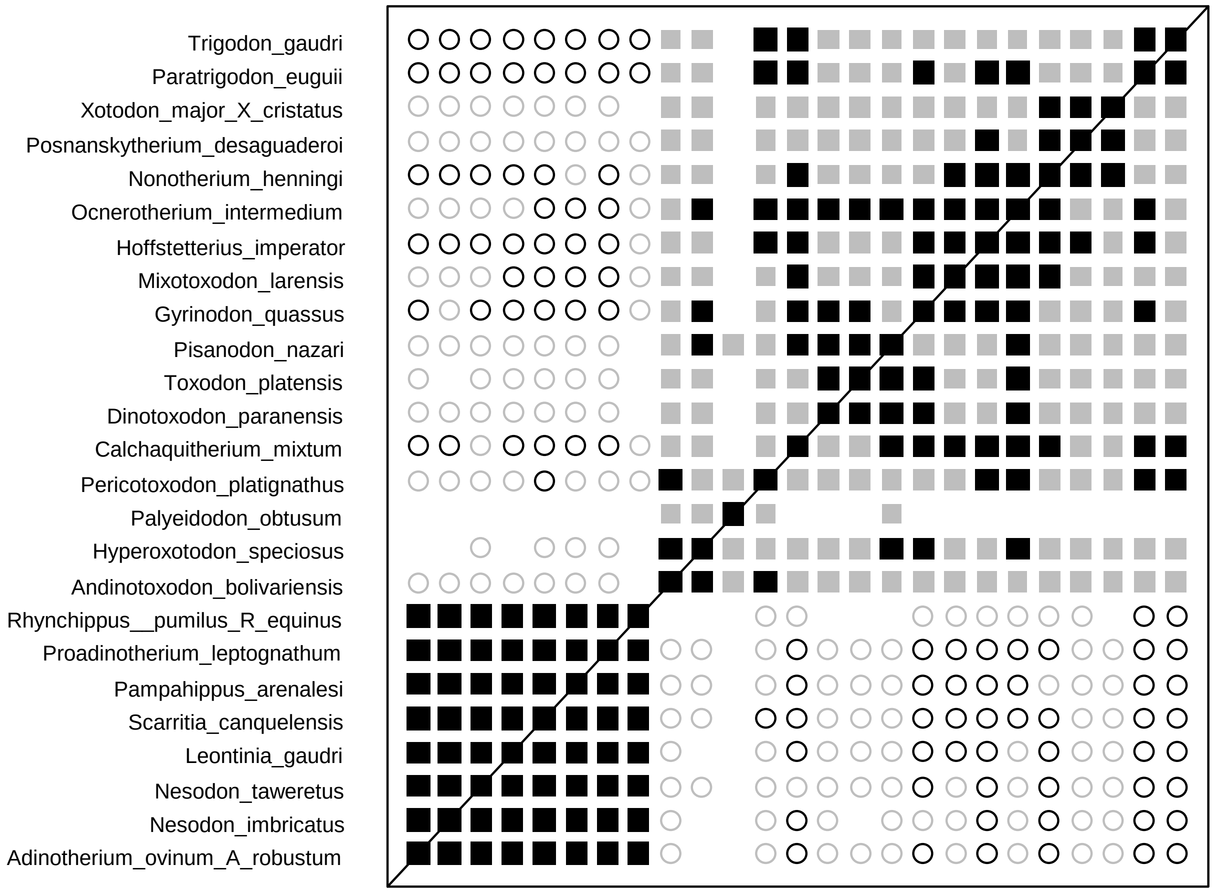


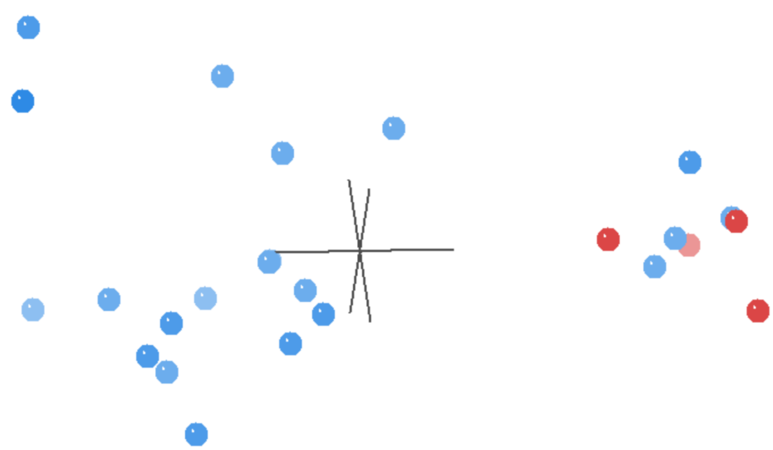
Order Notoungulata
Family Leontiniidae

Published taxa	27
Published characters	83
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	27
Characters used for calculations	36
Median bootstrap value	90
F_{90}	0.49
Stress of 3D MDS	0.13
k_{min}	4
Conclusion	HB

Notes: BDC and MDS reveal two groups corresponding to Leontiniidae and the outgroup. They are well separated in both analyses. Leontiniidae is likely a holobaramin.

Forasiepi, A.M., E. Cerdeno, M. Bond, G.I. Schmidt, M. Naipauer, F.R. Straehl, A.G. Martinelli, A.C. Garrido, M.D. Schmitz, and J.J. Crowley. 2015. New toxodontid (Notoungulata) from the early Miocene of Mendoza, Argentina. *Paläontologische Zeitschrift* 89:611-634.
Characters: Craniodental



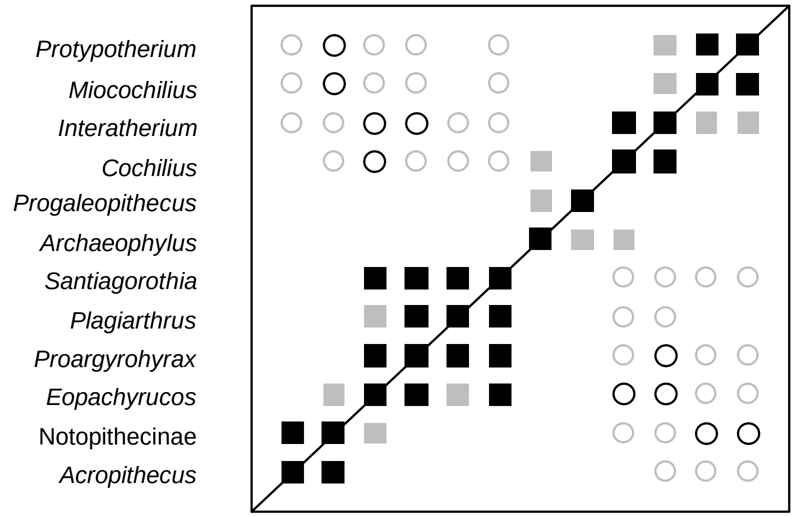


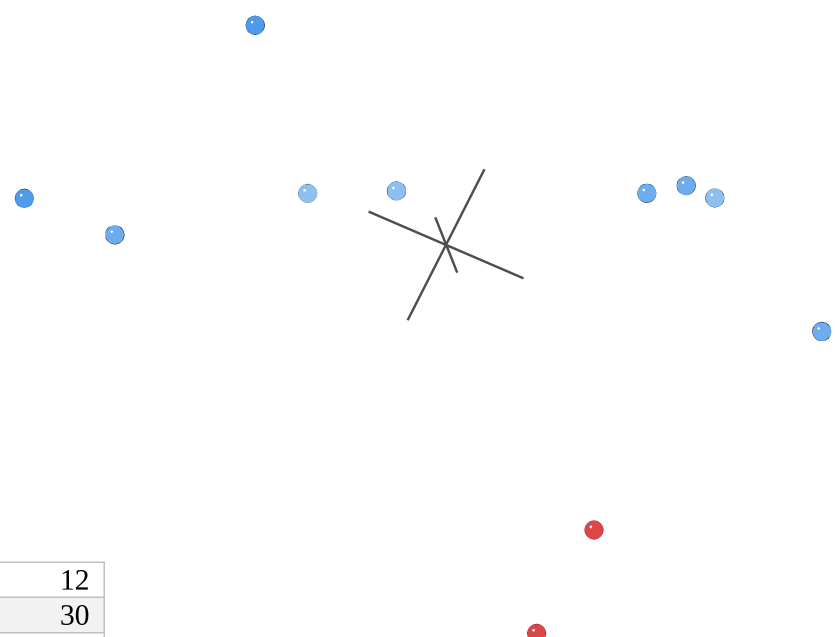
Order Notoungulata
Family Toxodontidae

Published taxa	25
Published characters	59
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	25
Characters used for calculations	33
Median bootstrap value	86
F_{90}	0.38
Stress of 3D MDS	0.14
k_{min}	4
Conclusion	HB

Notes: Two groups of taxa are distinguishable in the BDC and MDS results. The four outgroup taxa cluster with four basal toxodontids. Toxodontidae *sensu stricto* is a holobaramin.

Reguero, M.A., M. Ubilla, and D. Perea. 2003. A new species of *Eopachyrucos* (Mammalia, Notoungulata, Interatheriidae) from the late Oligocene of Uruguay. *Journal of Vertebrate Paleontology* 23:445-457.
Characters: Craniodental and postcranial



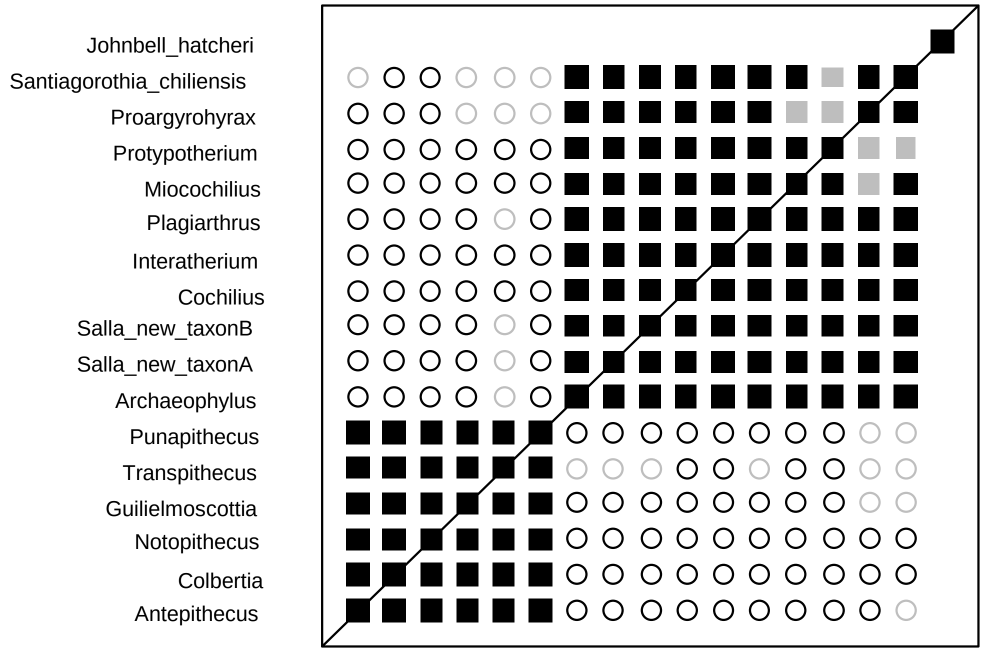


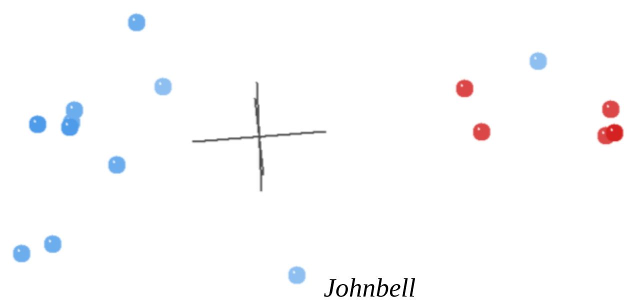
Order Notoungulata
Family Interatheriidae

Published taxa	12
Published characters	30
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	12
Characters used for calculations	26
Median bootstrap value	78.5
F_{90}	0.23
Stress of 3D MDS	0.08
k_{min}	3
Conclusion	Inc

Notes: BDC reveals two groups with no overlap, neither of which corresponds to a named taxonomic group. The MDS does not confirm these groups but instead shows separation between the ingroup Interatheriinae and two taxa corresponding to the outgroup *Acropithecus* and the composite interatheriid subfamily Notopithecinae. These results are inconclusive.

Hitz, R.B., J.J. Flynn, and A.R. Wyss. 2006. New basal Interatheriidae (Typotheria, Notoungulata, Mammalia) from the Paleogene of Central Chile. *American Museum Novitates* 3520:1-32.
Characters: Craniodental



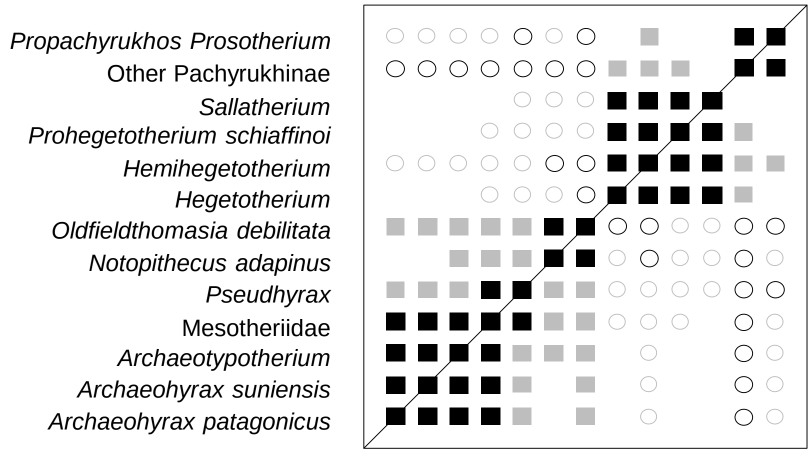


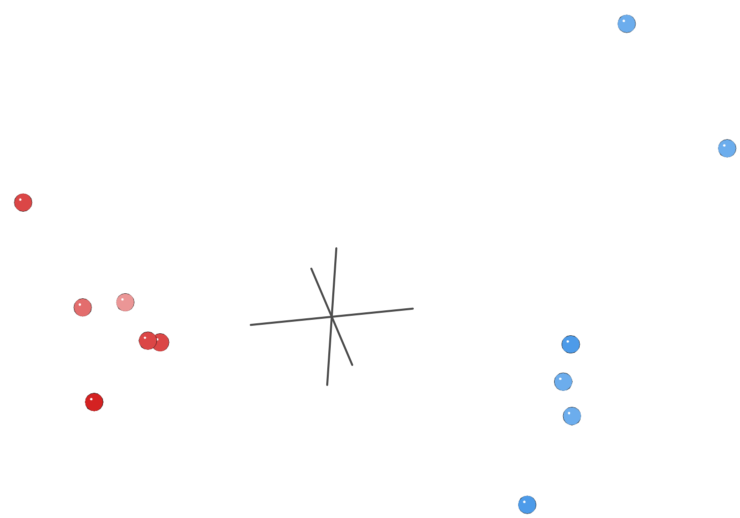
Order Notoungulata
Family Interatheriidae

Published taxa	21
Published characters	43
Character relevance	0.75
Taxic relevance	0.45
Taxa used for calculations	17
Characters used for calculations	21
Median bootstrap value	98
F_{90}	0.76
Stress of 3D MDS	0.04
k_{min}	3
Conclusion	HB

Notes: BDC and MDS support a distinct Interatheriidae cluster. The interatheriid *Punapithecus* clusters with the outgroup, and another, *Johnbell*, shares no BDC with any other taxa. Interatheriidae *sensu stricto* could be a holobaramin.

Billet, G., B. Patterson, and C. De Muizon. 2009. Craniodental anatomy of late Oligocene archaeohyracids (Notoungulata, Mammalia) from Bolivia and Argentina and new phylogenetic hypotheses. *Zoological Journal of the Linnean Society* 155:458-509.
Characters: Craniodental and postcranial



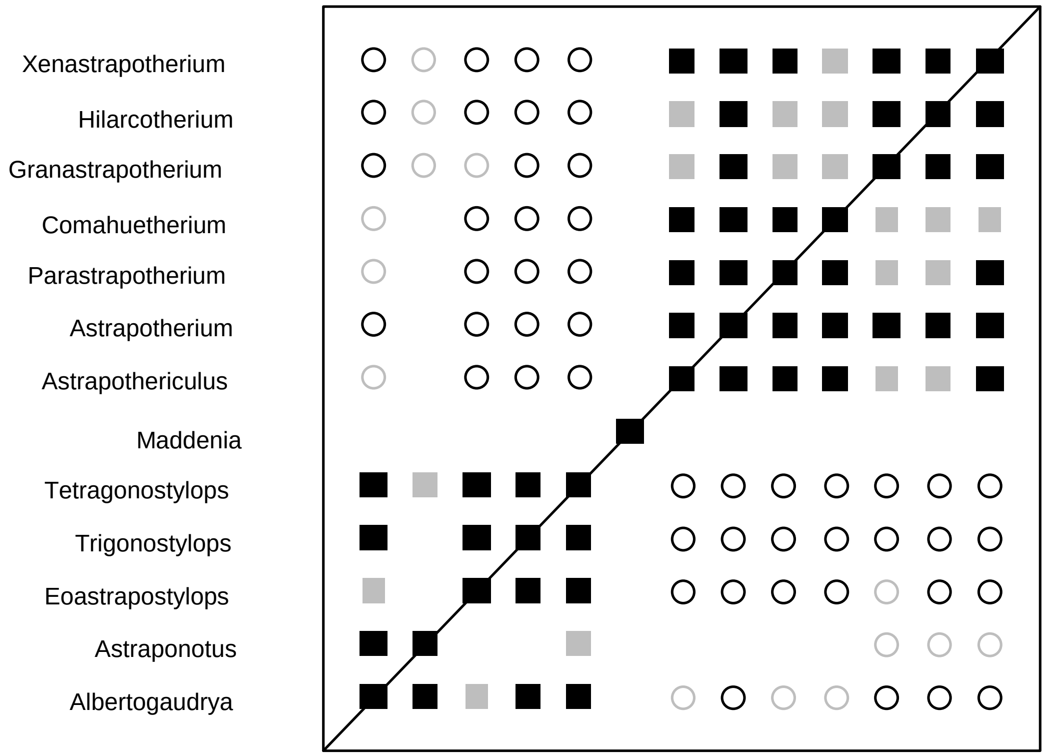


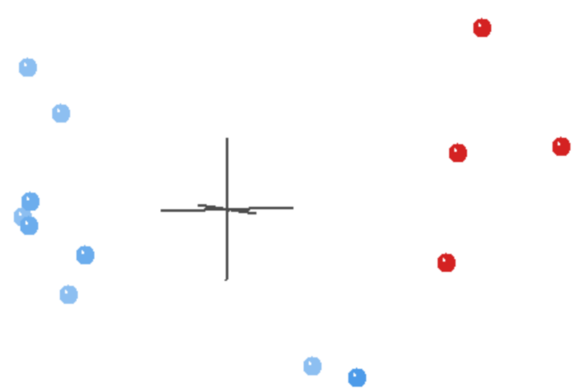
Order Notoungulata
Family Hegetotheriidae

Published taxa	15
Published characters	39
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	13
Characters used for calculations	32
Median bootstrap value	82.5
F_{90}	0.29
Stress of 3D MDS	0.07
k_{min}	3
Conclusion	HB

Notes: Hegetotheriidae and outgroup taxa are well-separated in both BDC and MDS results. Hegetotheriidae is likely a holobaramin.

Vallejo-Pareja, M.C., J.D. Carrillo, J.W. Moreno-Bernal, M. Pardo-Jaramillo, D.F. Rodriguez-Gonzalez, and J. Muñoz-Duran. 2015. *Hilarcotherium castanedaii*, gen. et sp. nov., a new Miocene astrapothere (Mammalia, Astrapotheriidae) from the Upper Magdalena Valley, Colombia. *Journal of Vertebrate Paleontology* 35:e903960.
Characters: Craniodental



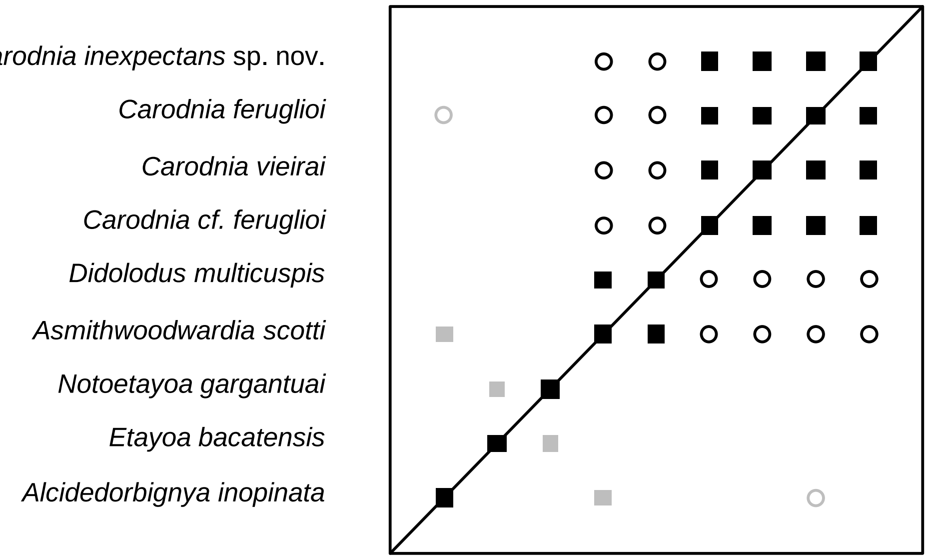


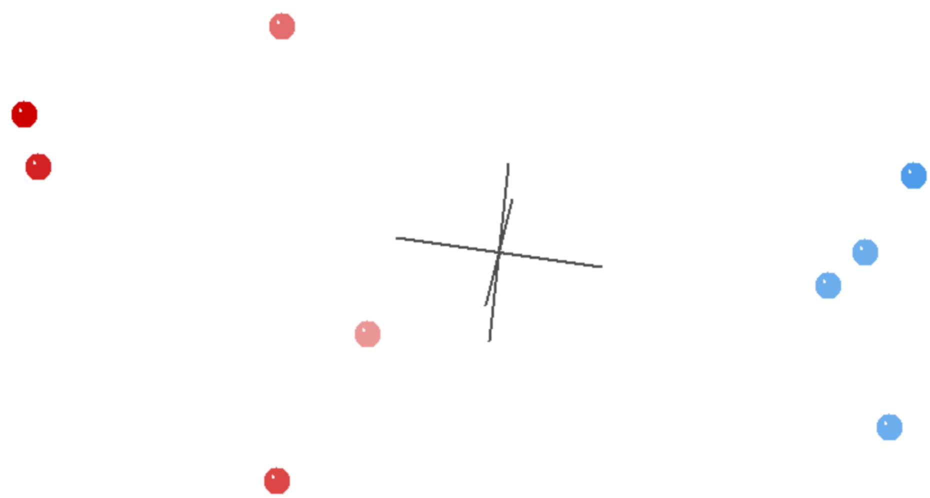
Order Astrapotheria
Family Astrapotheriidae

Published taxa	15
Published characters	64
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	13
Characters used for calculations	45
Median bootstrap value	93
F_{90}	0.59
Stress of 3D MDS	0.09
k_{min}	5
Conclusion	HB

Notes: BDC and MDS reveal two well-separated groups. One astrapotheriid *Astraponotus* clusters with the outgroup taxa, and *Maddenia* does not cluster with either larger group. Astrapotheriidae *sensu stricto* (excluding *Astraponotus* and *Maddenia*) is probably a holobaramin.

Antoine, P.O., G. Billet, R. Salas-Gismondi, J.T. Lara, P. Baby, S. Brusset, and N. Espurt. 2015. A new *Carodnia* Simpson, 1935 (Mammalia, Xenungulata) from the early Eocene of Northwestern Peru and a phylogeny of xenungulates at species level. *Journal of Mammalian Evolution* 22:129-140.
Characters: Craniodental



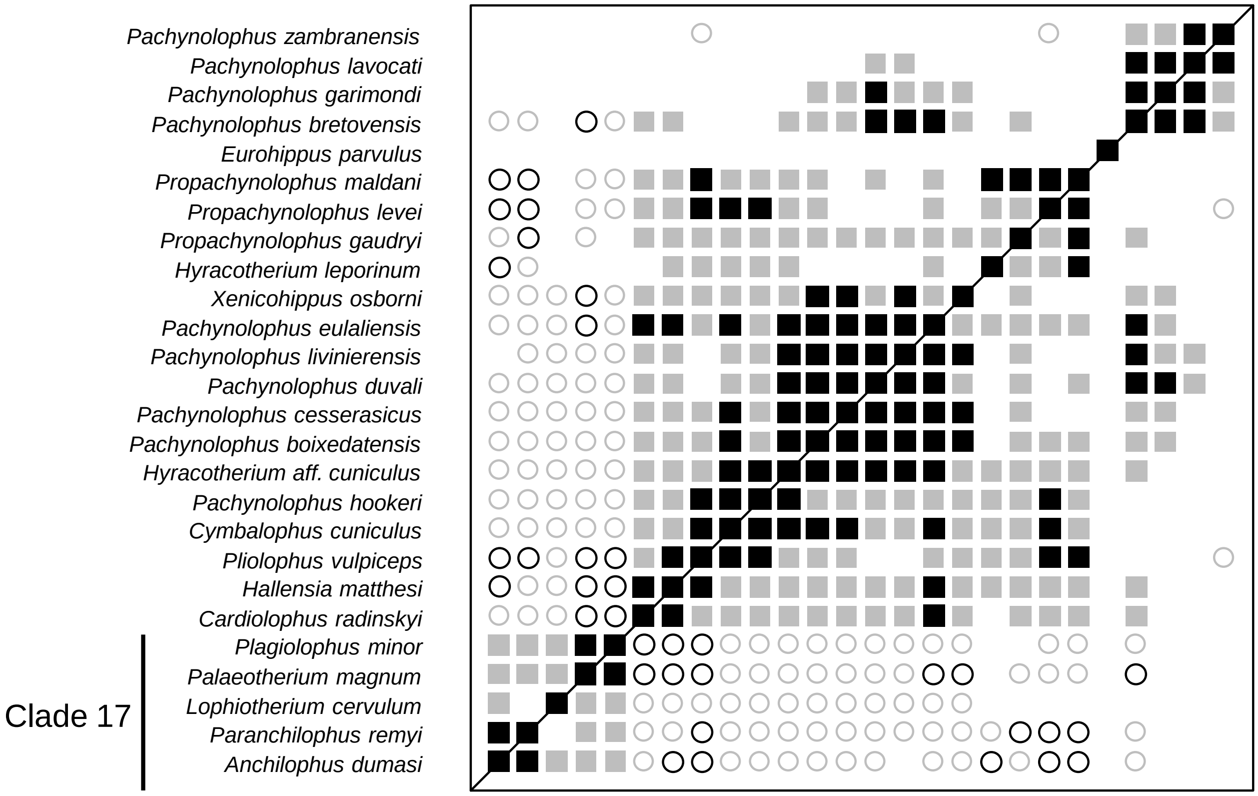


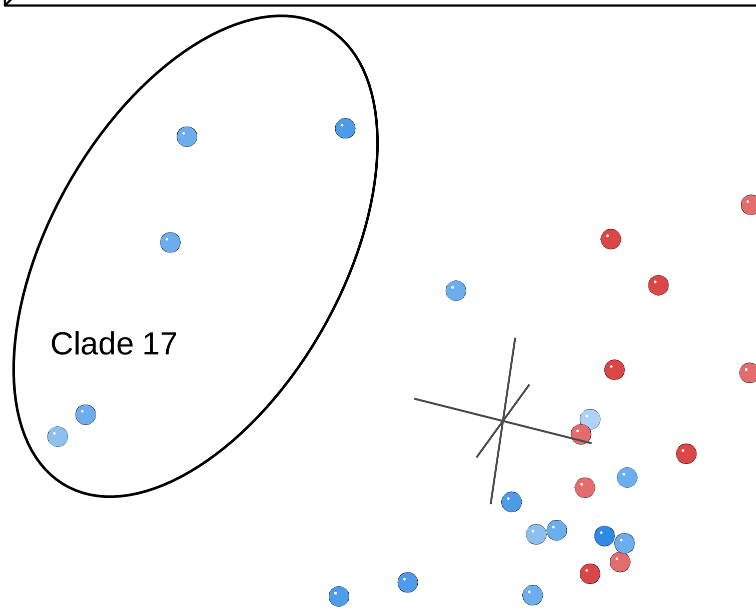
Order Xenungulata
Family Carodniidae

Published taxa	9
Published characters	34
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	9
Characters used for calculations	28
Median bootstrap value	92.5
F_{90}	0.53
Stress of 3D MDS	0.1
k_{min}	3
Conclusion	HB?

Notes: BDC and MDS reveal two well-separated groups of Carodniidae and outgroup taxa. Carodniidae is likely a holobaramin.

Danilo, L., J.A. Remy, M. Vianey-Liaud, B. Marandat, J. Sudre, and F. Lihoreau. 2013. A new Eocene locality in southern France sheds light on the basal radiation of Palaeotheriidae (Mammalia, Perissodactyla, Equoidea). *Journal of Vertebrate Paleontology* 33:195-215.
Characters: Craniodental



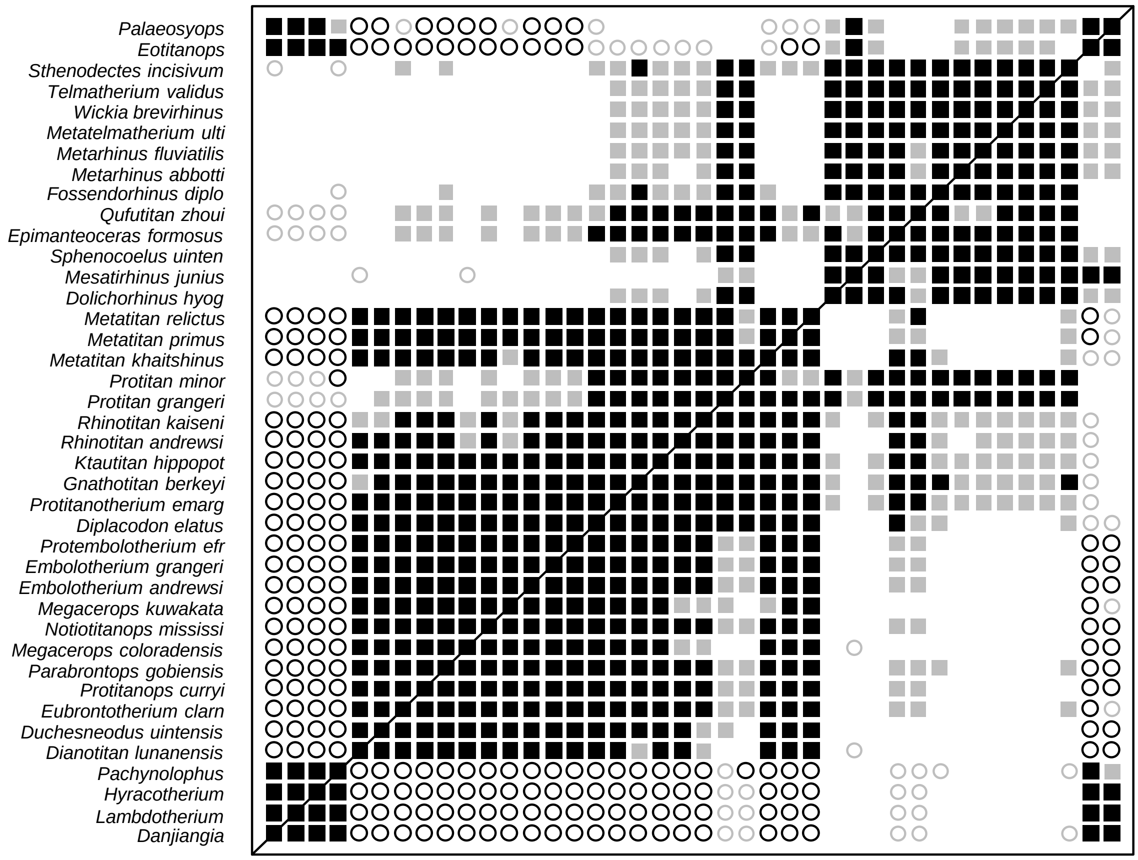


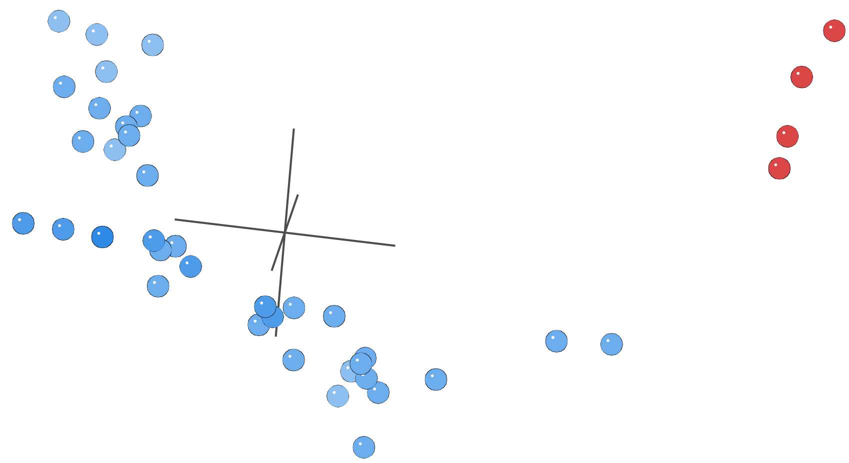
Order Perissodactyla
Family Palaeotheriidae

Published taxa	26
Published characters	72
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	26
Characters used for calculations	57
Median bootstrap value	81
F_{90}	0.22
Stress of 3D MDS	0.25
k_{min}	8
Conclusion	HB?

Notes: BDC indicates good evidence for discontinuity around a group of five taxa corresponding to clade 17 in Danilo et al.'s (2013) Figure 9. MDS seems to support the separation of this cluster of taxa. Clade 17 includes Palaeotheriinae (*Plagiolophus minor*, *Palaeotherium magnum*) and three additional taxa included here: *Lophiotherium cervulum*, *Paranchilophus remyi*, and *Anchilophus dumasi*. Clade 17 could be a holobaramin.

Mihlbachler, M.C. 2008. Species taxonomy, phylogeny, and biogeography of the Brontotheriidae (Mammalia: Perissodactyla). *Bulletin of the American Museum of Natural History* 311:1-475.
Characters: Craniodental



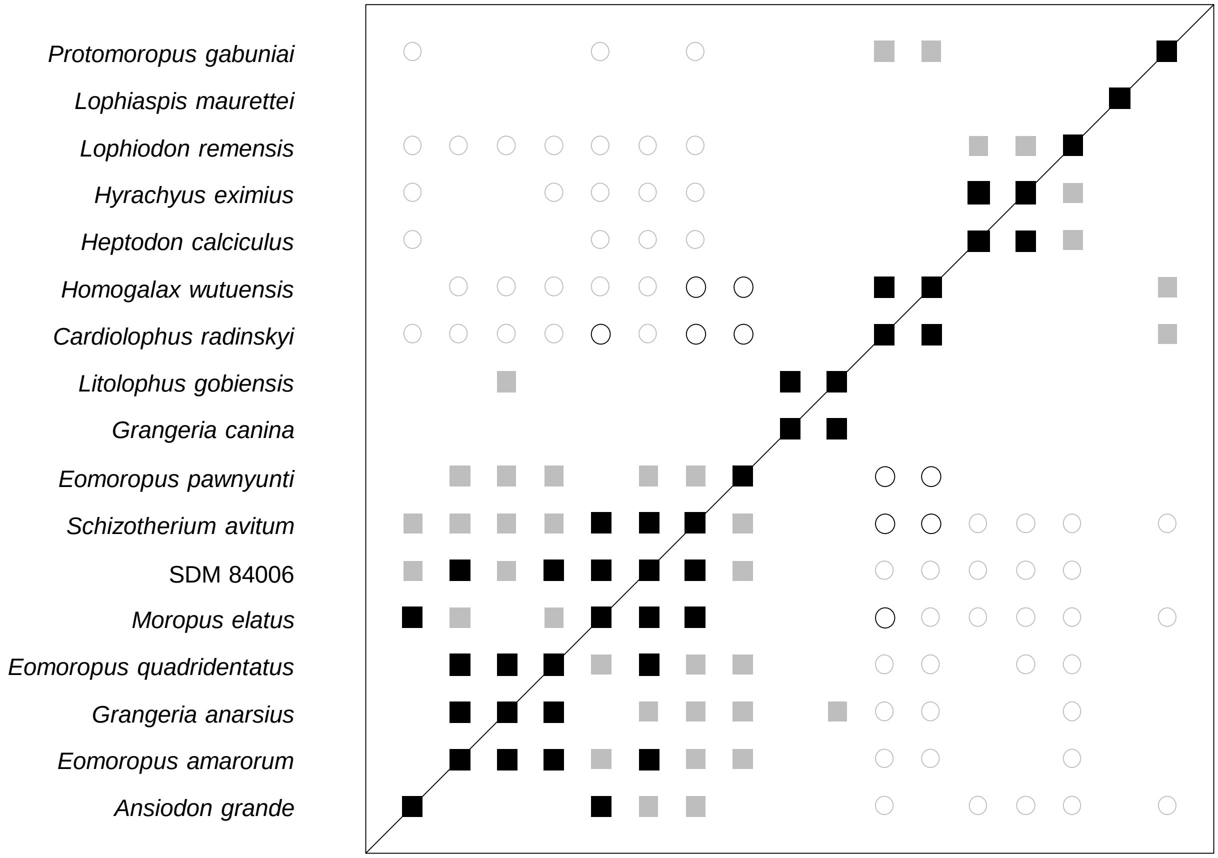


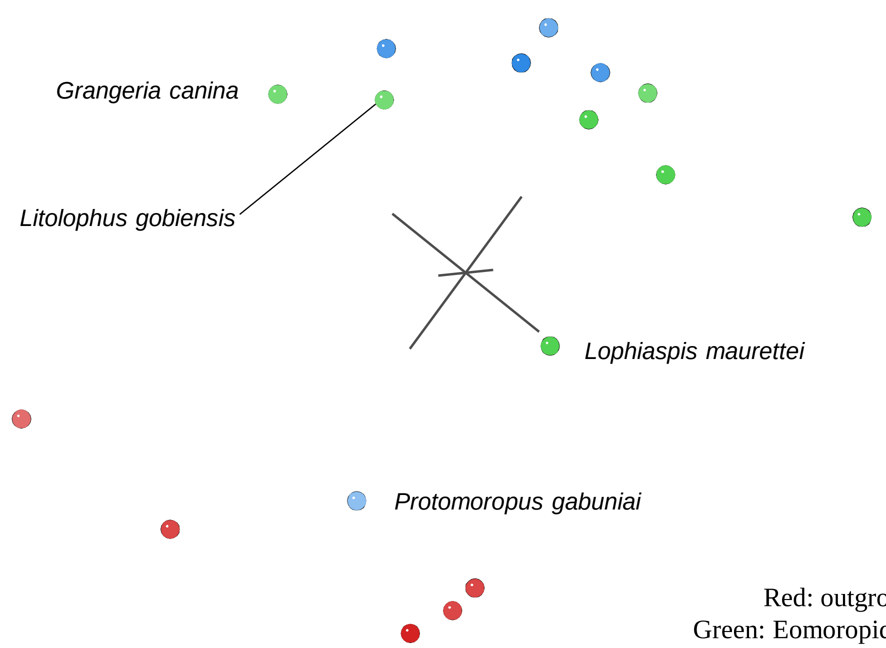
Order Perissodactyla
Family Brontotheriidae

Published taxa	51
Published characters	87
Character relevance	0.75
Taxic relevance	0.5
Taxa used for calculations	40
Characters used for calculations	81
Median bootstrap value	94
F_{90}	0.53
Stress of 3D MDS	0.17
k_{min}	7
Conclusion	HB?

Notes: In BDC, the Brontotheriidae are well separated from the outgroup, except for two brontotheres, *Paleosyops* and *Eotitanops*, which share significant, positive BDC with all outgroup taxa. The MDS shows an arc of taxa but with a separation between the outgroup and the Brontotheriidae. This suggests that the correlations involving the outgroups, *Paleosyops*, and *Eotitanops* are a result of the linear geometry of the brontothere taxa. Taken together, this suggests that Brontotheriidae is likely a holobaramin.

Bai, B., Y. Wang, and J. Meng. 2010. New craniodental materials of *Litolophus gobiensis* (Perissodactyla, "Eomoropidae") from Inner Mongolia, China, and phylogenetic analyses of Eocene chalicotheres. *American Museum Novitates* 3688:1-27.
Characters: Craniodental



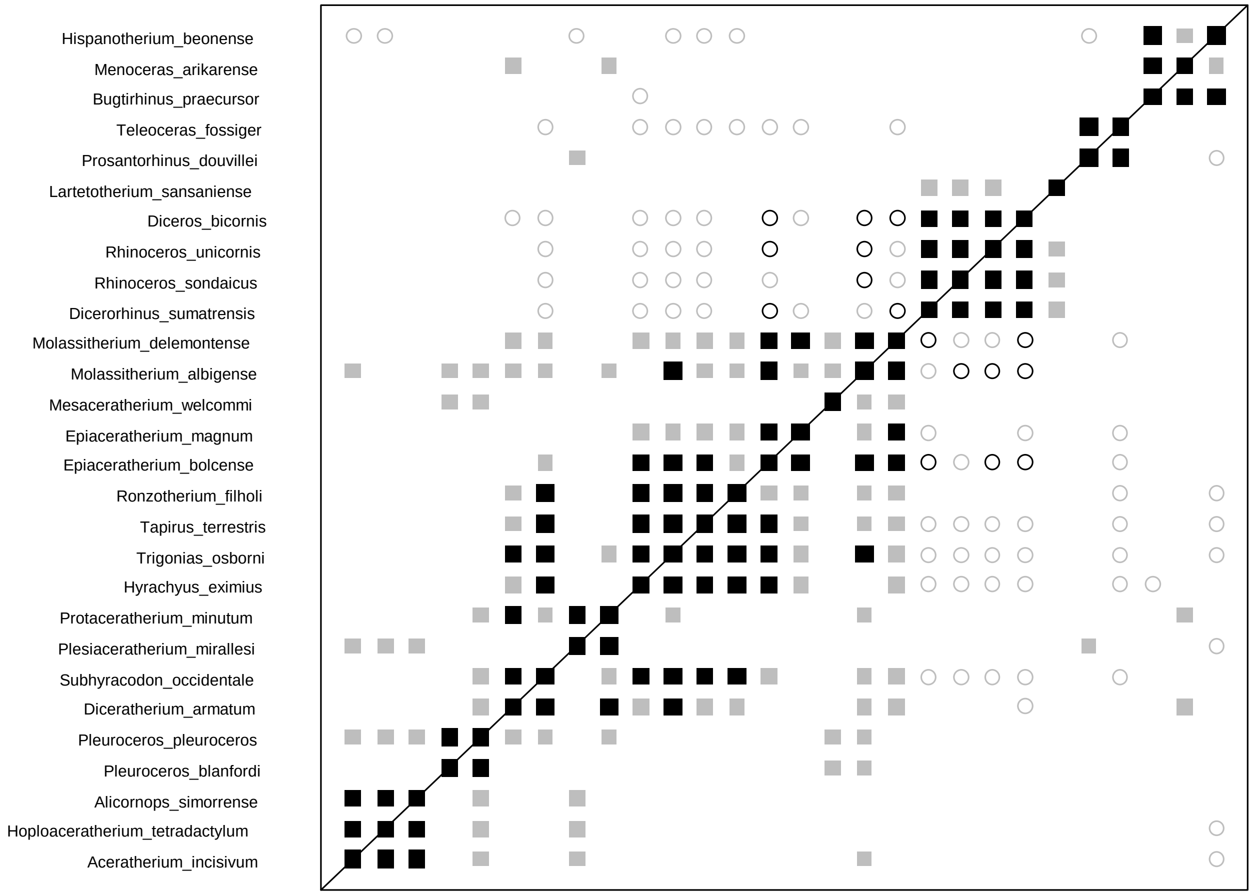


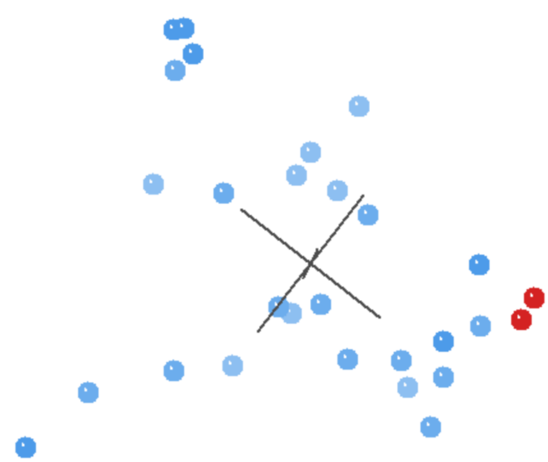
Order Perissodactyla
Family Chalicotheriidae

Published taxa	21
Published characters	58
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	17
Characters used for calculations	38
Median bootstrap value	77
F_{90}	0.16
Stress of 3D MDS	0.2
k_{min}	6
Conclusion	HB?

Notes: The BDC results reveal two groups of taxa, corresponding roughly to the chalicotheres and other taxa. The two groups are well-separated, but the chalicothere *Protomoropus* is part of the outgroup. The chalicothere *Lophiaspis* does not share significant BDC with any other taxa. The MDS results reveal the same groups with *Protomoropus* in the outgroup cluster and *Lophiaspis* in between the two clusters. The chalicotheres (excluding *Protomoropus* and *Lophiaspis*) are likely a holobaramin.

Becker, D., P.O. Antoine, and O. Maridet. 2013. A new genus of Rhinocerotidae (Mammalia, Perissodactyla) from the Oligocene of Europe. *Journal of Systematic Palaeontology* 11:947-972.
Characters: Craniodental and postcranial



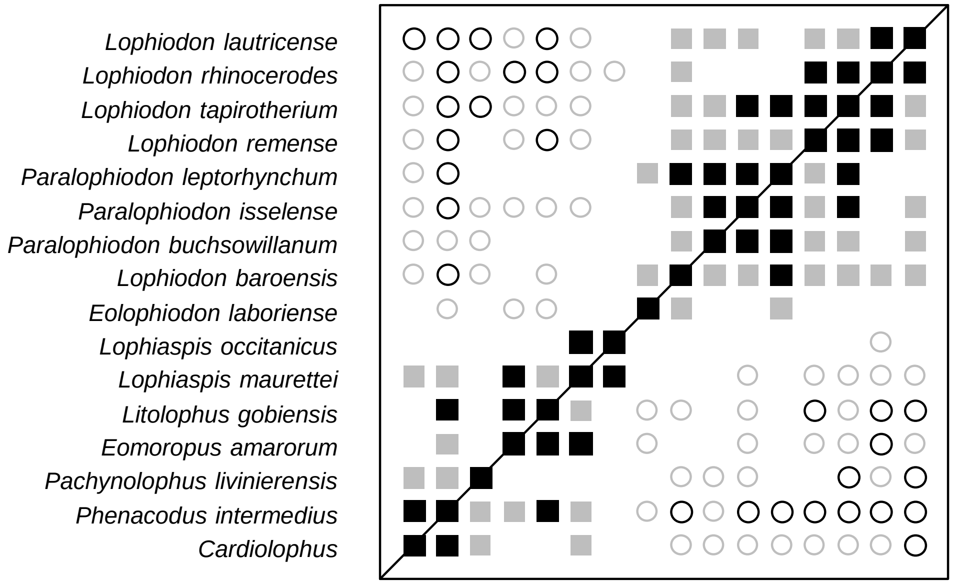


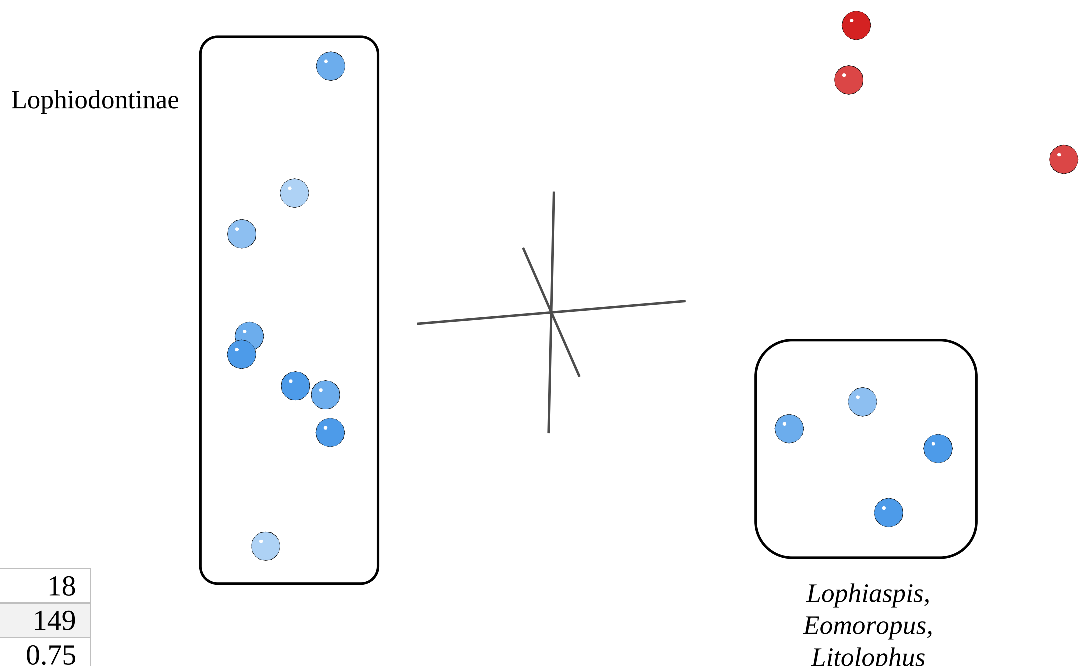
Order Perissodactyla
Family Rhinocerotidae

Published taxa	30
Published characters	214
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	28
Characters used for calculations	161
Median bootstrap value	89
F_{90}	0.45
Stress of 3D MDS	0.34
k_{min}	15
Conclusion	Inc

Notes: No evidence of discontinuity.

Robinet, C., J.A. Remy, J.A., Y. Laurent, L. Danilo, and F. Lihoreau. 2015. A new genus of Lophiodontidae (Perissodactyla, Mammalia) from the early Eocene of La Borie (Southern France) and the origin of the genus *Lophiodon* Cuvier, 1822. *Geobios* 48:25-38.
Characters: Craniodental



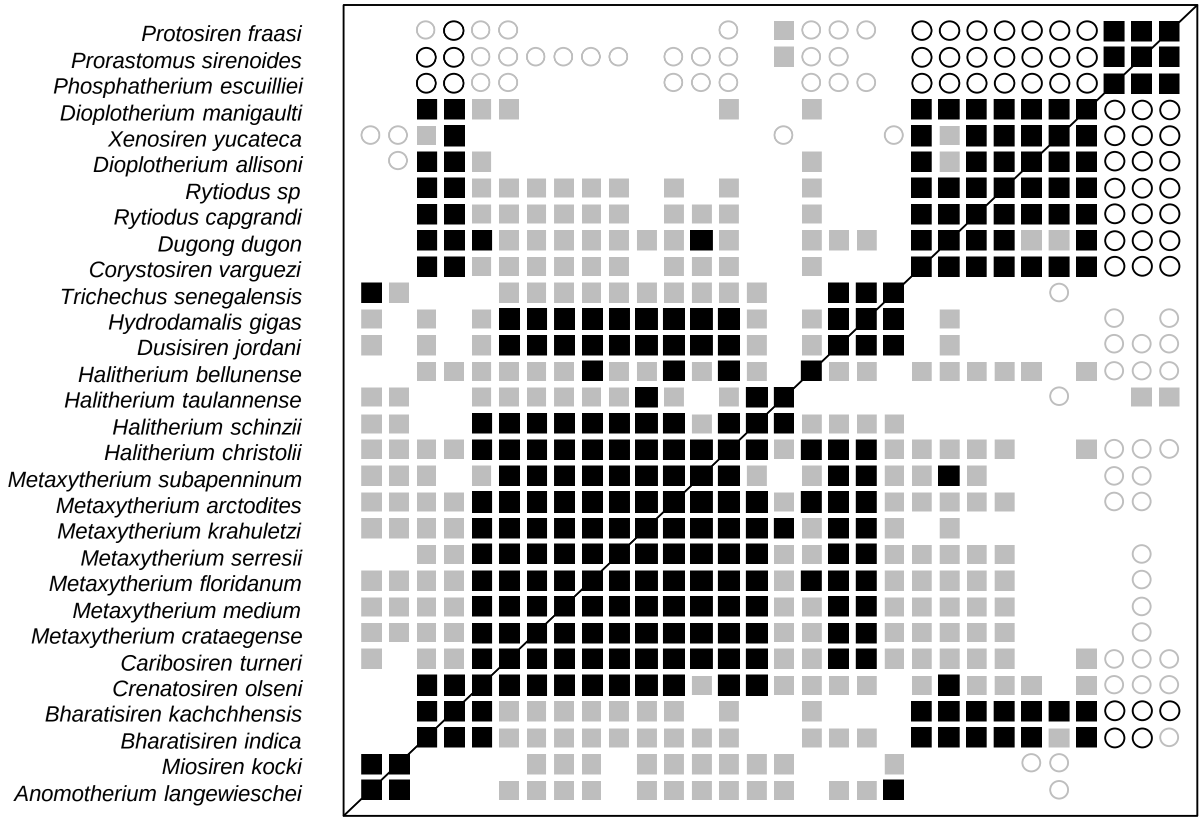


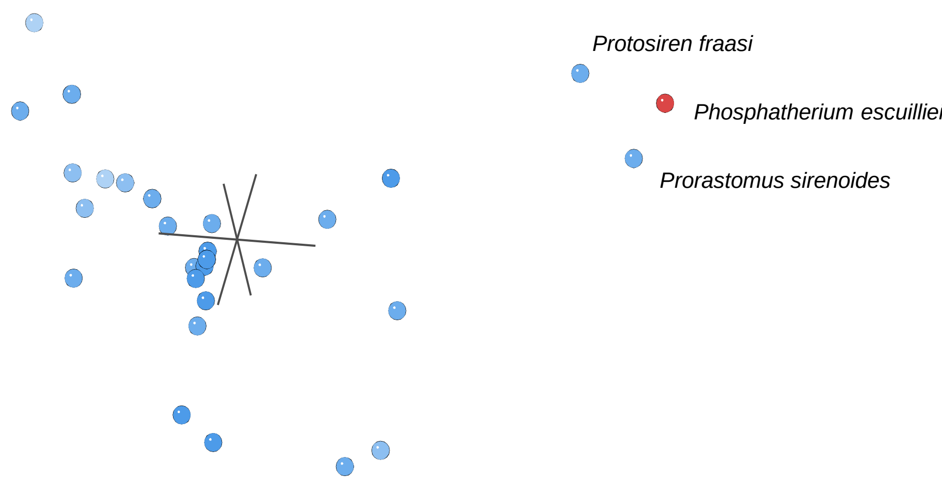
Order Perissodactyla
Family Lophiodontidae

Published taxa	18
Published characters	149
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	16
Characters used for calculations	118
Median bootstrap value	77
F_{90}	0.28
Stress of 3D MDS	0.24
k_{min}	10
Conclusion	HB

Notes: BDC and MDS both support two distinct groups, one consisting of subfamily Lophiodontinae (*Lophiodon*, *Paralophiodon*, and *Eolophiodon*), and the other containing all other taxa. Lophiodontinae is likely a holobaramin.

Sorbi, S. 2008. The Neogene Euro-North African Sirenia: phylogenetic and systematic study, palaeoecological and palaeobiogeographic considerations. Ph.D. Dissertation. Pisa: Università di Pisa.
Characters: Craniodental



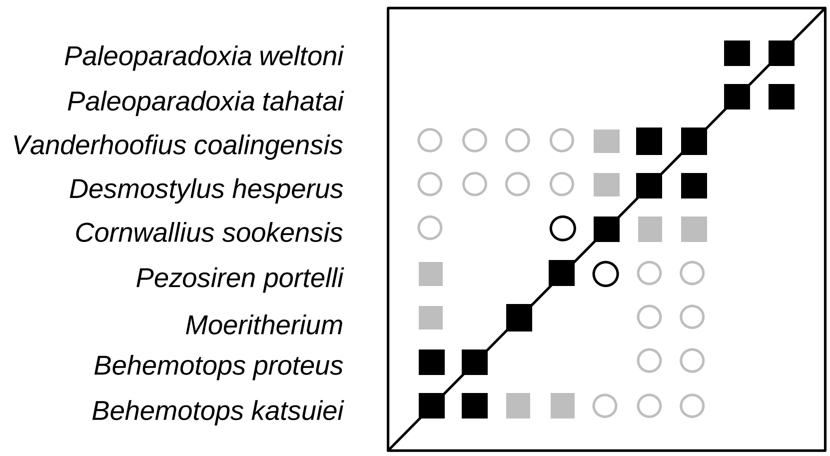


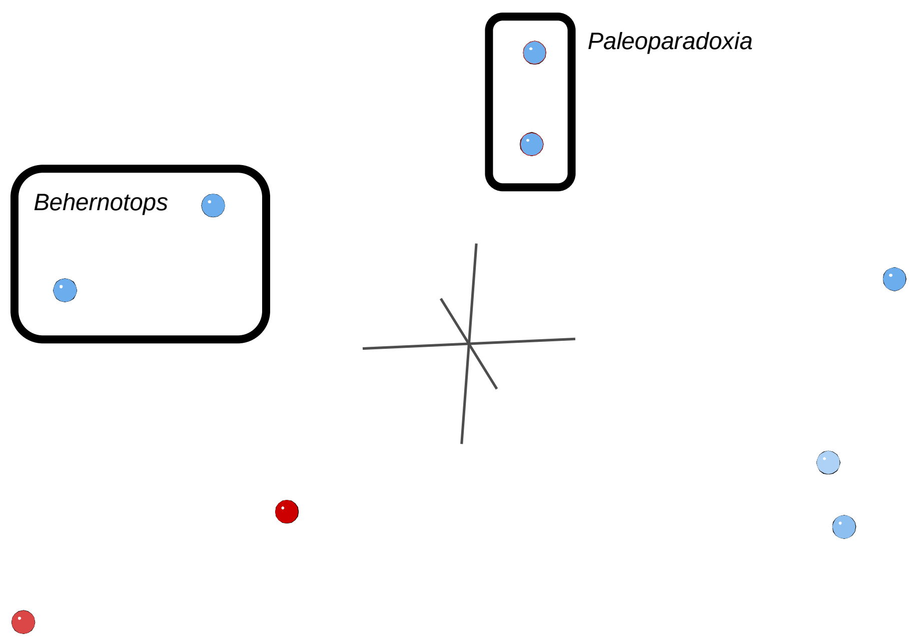
Order Uranotheria
Infraorder Sirenia

Published taxa	32
Published characters	57
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	7
Characters used for calculations	50
Median bootstrap value	78
F_{90}	0.33
Stress of 3D MDS	0.16
k_{min}	5
Conclusion	HB

Notes: BDC and MDS both support two groups: 1. The outgroup *Phosphatherium escuilliei* together with the sirenians *Protosiren fraasi* and *Prorastomus sirenoides*. 2. The rest of the Sirenia. There is significant, positive BDC with low bootstrap values only between *Halitherium taulannense* and the two sirenians that cluster with the outgroup, but in the MDS results, *Halitherium taulannense* is part of the sirenian cluster and separate from the three taxa in the outgroup cluster. We may infer that Sirenia *sensu stricto* (excluding *Protosiren* and *Prorastomus*) is a holobaramin.

Beatty, B.L. 2009. New material of *Cornwallius sookensis* (Mammalia: Desmostylia) from the Yaquina Formation of Oregon. *Journal of Vertebrate Paleontology* 29:894-909.
Characters: Craniodental



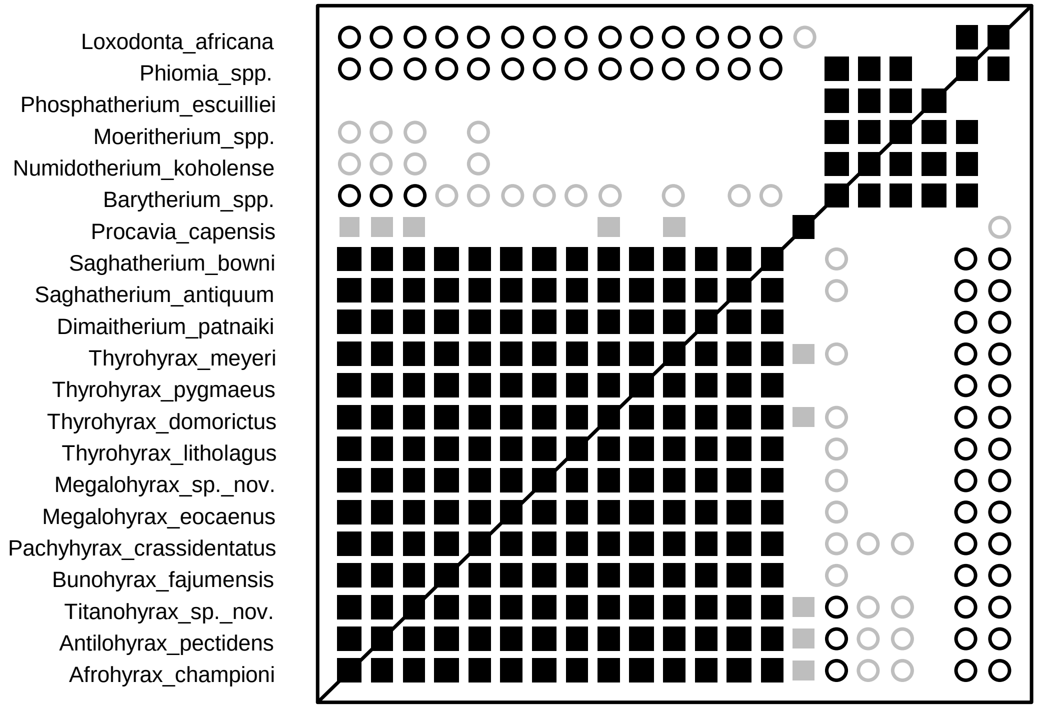


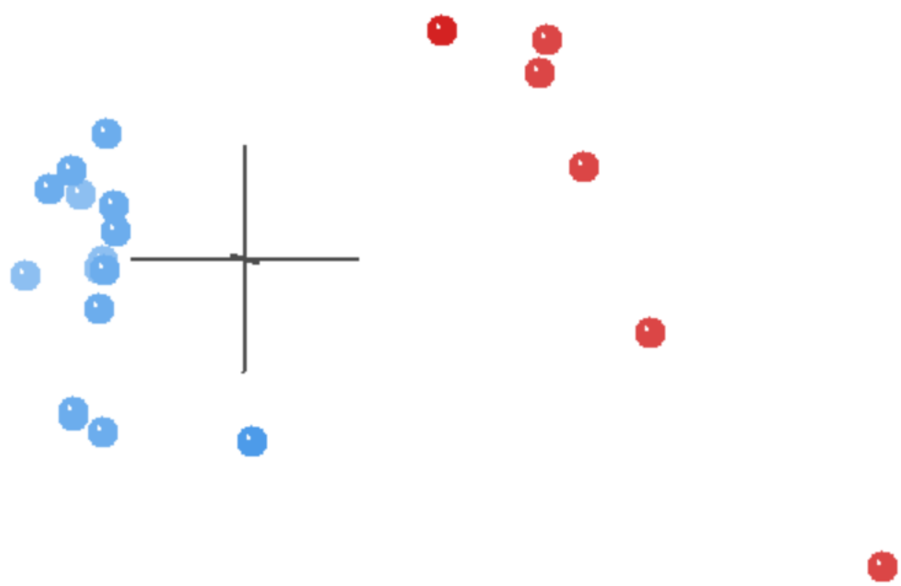
Order Uranotheria
Family Desmostylidae

Published taxa	10
Published characters	37
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	9
Characters used for calculations	25
Median bootstrap value	83.5
F_{90}	0.28
Stress of 3D MDS	0.1
k_{min}	3
Conclusion	HB?

Notes: BDC results reveal three clusters: 1. the *Palaeoparadoxia* species, 2. the desmostylids *Vanderhoofius*, *Desmostylus*, and *Cornwallius*, and 3. the remaining taxa. There is significant, negative BDC between the restricted desmostylid group and the outgroup taxa. Bootstrap values for all BDC are poor. The MDS results reveal four clusters, separating the *Behemotops* species from the remaining outgroup taxa. We may provisionally accept the restricted Desmostylidae *sensu stricto* (*Vanderhoofius*, *Desmostylus*, and *Cornwallius*) as a holobaramin.

Seiffert, E.R., S. Nasir, A. Al-Harthy, J.R. Groenke, B.P. Kraatz, N.J. Stevens, and A.R. Al-Sayigh. 2012. Diversity in the later Paleogene proboscidean radiation: a small barytheriid from the Oligocene of Dhofar Governorate, Sultanate of Oman. *Naturwissenschaften* 99:133-141.
Characters: Craniodental, postcranial, soft tissue



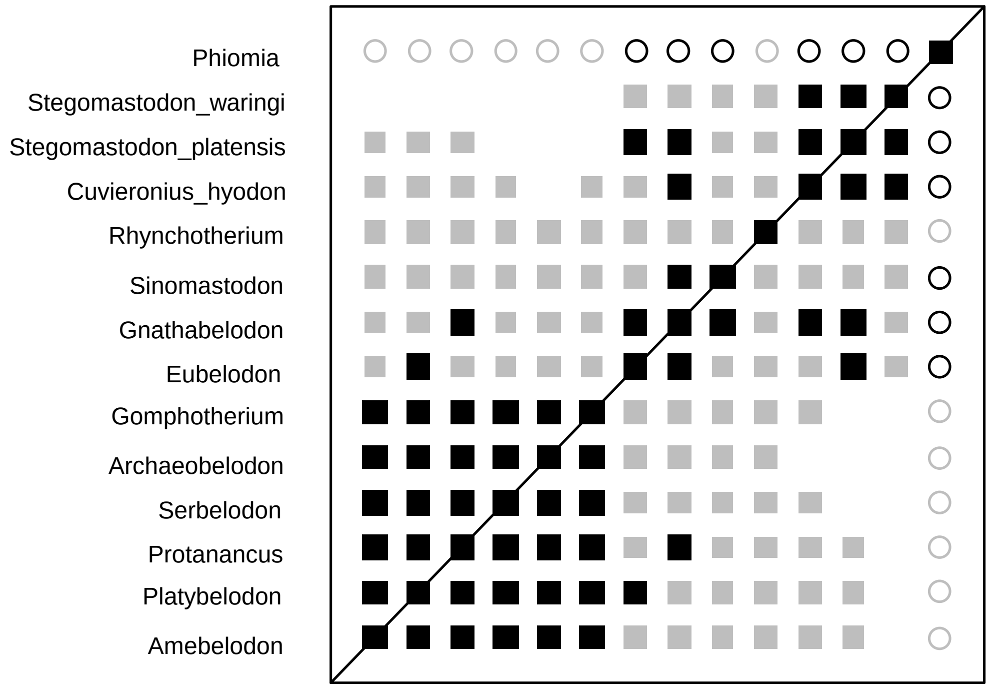


Order Hyracoidea
Family Procaviidae

Published taxa	63
Published characters	422
Character relevance	0.75
Taxic relevance	0.4
Taxa used for calculations	21
Characters used for calculations	208
Median bootstrap value	100
F_{90}	0.75
Stress of 3D MDS	0.25
k_{min}	15
Conclusion	HB

Notes: Procaviidae is well separated from the outgroup taxa in BDC and MDS results. Procaviidae is likely a holobaramin.

Cozzuol, M.A., D. Mothé, and L.S. Avilla. 2012. A critical appraisal of the phylogenetic proposals for the South American Gomphotheriidae (Proboscidea: Mammalia). *Quaternary International* 255:36-41.
Characters: Craniodental and postcranial

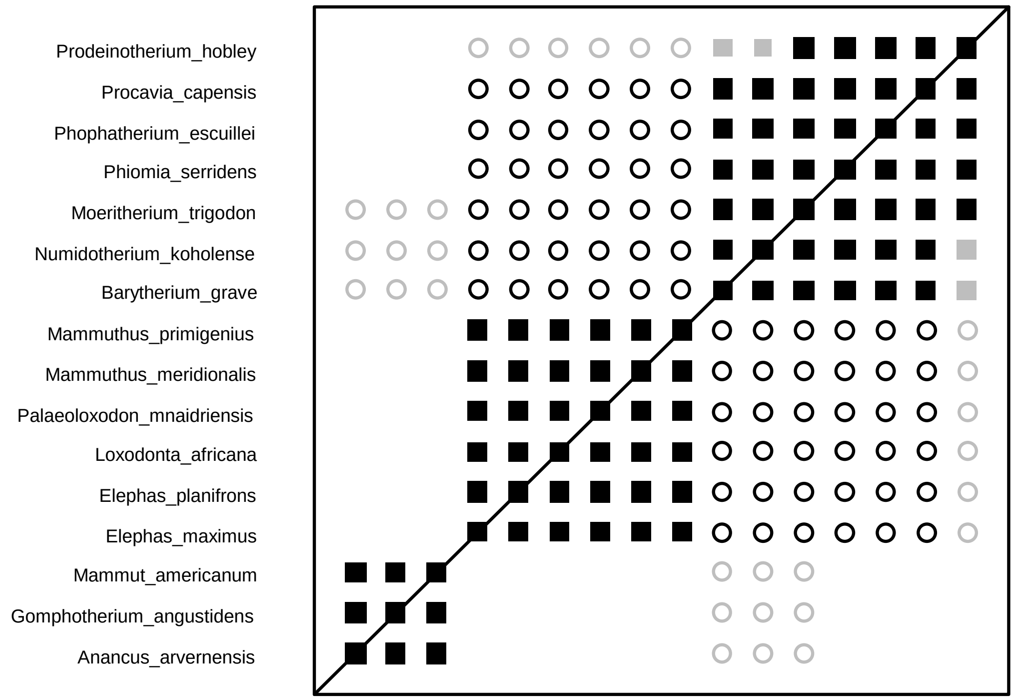


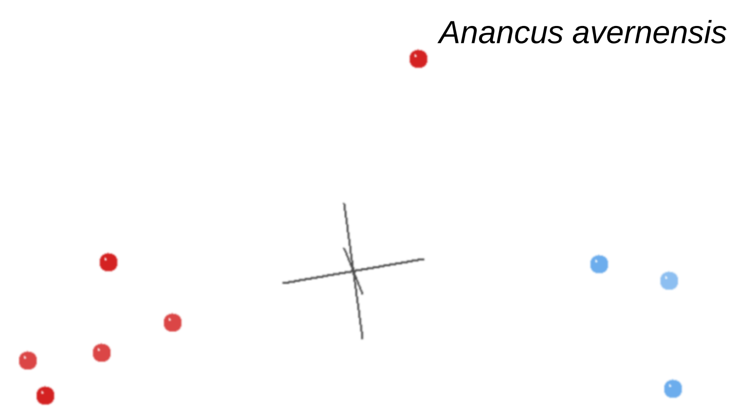
Order Proboscidea
Family Gomphotheriidae

Published taxa	14
Published characters	43
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	14
Characters used for calculations	34
Median bootstrap value	85
F_{90}	0.33
Stress of 3D MDS	0.11
k_{min}	5
Conclusion	HB?

Notes: Gomphotheriidae is well separated from the outgroup taxa in BDC and MDS results. Gomphotheriidae is likely a holobaramin; although, the outgroup may not be suitable for these taxa.

Ferretti, M.P. and R. Debruyne. 2010. Anatomy and phylogenetic value of the mandibular and coronoid canals and their associated foramina in proboscideans (Mammalia). *Zoological Journal of the Linnean Society* 161:391-413.
Characters: Cranial





Order Proboscidea
Family Elephantidae

Published taxa	16
Published characters	10
Character relevance	0.75
Taxic relevance	0
Taxa used for calculations	16
Characters used for calculations	10
Median bootstrap value	97
F_{90}	0.61
Stress of 3D MDS	0.03
k_{min}	3
Conclusion	HB?

Notes: BDC and MDS reveal Elephantidae clearly separated from the outgroup taxa. Elephantidae is likely a holobaramin. The ten characters are not remotely holistic, so the elephantid holobaramin should be considered extremely provisional.